DOCUMENT RESUME

ED 221 758 CE 034 085

TITLE Engineering Drawing II, 6-2. Military Curriculum Project for Vocational and Technical Education.
INSTITUTION Army Engineer School, Fort Belvoir, Va.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY Office of Education (DHEW), Washington, D.C.
PUB DATE 78
NOTE 233p.; For a related document see CE 034 084.

EDRS PRICE MF01/PC10 Plus Postage.
DESCRIPTORS *Architectural Drafting; *Engineering Drawing; Maps; Military Personnel; Military Training; Postsecondary Education; *Reprography; Secondary Education; *Technical Education; *Technical Illustration
IDENTIFIERS Military Curriculum Project

ABSTRACT

This military-developed text consists of seven lessons to teach students with basic drafting skills more advanced techniques. Covered in the individual lessons are the following topics: auxiliary views; isometric drawing; screws, bolts, rivets, and welds; detail and assembly practices; intersections and developments; machine drawing; architectural and structural drawing; map drawing; and drawing reproduction. Each lesson contains objectives, readings, review exercises, answers to the exercises, and practice drawings. The material is designed for self-paced, individualized instruction. (MN)

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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
Joseph F. Kelly, Ph.D.
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225 West State Street
Trenton, NJ 08625
609/292-6562

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

ENGINEERING DRAWING II

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ENGINEERING DRAWING II

Correspondence Course

6-2

Developed by:

United States Army

Development and Review Dates:

Unknown

Occupational Area:

Drafting

Cost:

Print Pages:

Availability:

Military Curriculum Project, The Center
for Vocational Education, 1960 Kenny
Rd., Columbus, OH 43210

Suggested Background:

Engineering Drawing I or the equivalent (basic drafting skills)

Target Audiences:

Grades 10-adult

Organization of Materials:

Text including objectives, readings, review exercises, and solutions and discussion of exercises; practice and assignment drawing plates

Type of Instruction:

Individualized, self-paced

Type of Materials:	No. of Pages:	Average Completion Time:
Engineering Drawing II		
Lesson 1 — Auxiliary Views	12	Flexible
Lesson 2 — Isometric Drawing	13	Flexible
Lesson 3 — Screws, Bolts, Rivets, and Welds	18	Flexible
Lesson 4 — Detail and Assembly Practices	34	Flexible
Lesson 5 — Intersections and Developments	14	Flexible
Lesson 6 — Machine Drawing	18	Flexible
Lesson 7 — Architectural and Structural Drawing	20	Flexible
Lesson 8 — Map Drawing	13	Flexible
Lesson 9 — Drawing Reproduction	9	Flexible
Practice and Exercise Plates	20	Flexible

Supplementary Materials Required:

Drafting Kit

Course Description:

This course consists of seven lessons to teach students with basic drafting skills more advanced techniques. The material presents a learning by doing format and allows students to practice through drawing plates which require application of the principles presented in the readings.

Lesson 1 – *Auxiliary Views* teaches the student to use auxiliary planes of projection to show the true size and shape of plane surfaces.

Lesson 2 – *Isometric Drawing* explains how to make isometric drawings and how to acquaint their pictorial value to a nontechnical audience.

Lesson 3 – *Screws, Bolts, Rivets, and Welds* discusses how to draw common fasteners used to connect assembled parts.

Lesson 4 – *Detail and Assembly Practices* shows the relationships between detail and assembly drawings and the practices for making them.

Lesson 5 – *Intersections and Developments* explains how to find the intersection of two geometric surfaces and how to draw all surfaces of an object in their "rolled-out-flat" form.

Lesson 6 – *Machine Drawing* discusses how to draw elementary mechanisms used in the design of machines.

Lesson 7 – *Architectural and Structural Drawing* shows how to draw elementary architectural and structural drawings.

Lesson 8 – *Map Drawing* discusses elementary methods of map drawing.

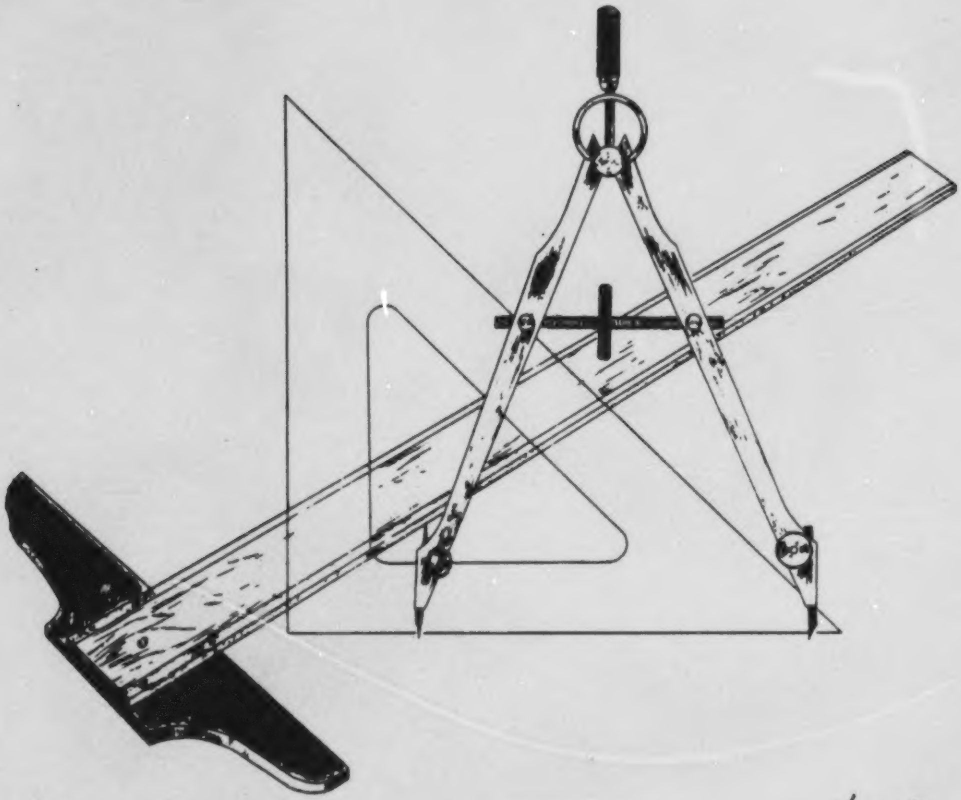
Lesson 9 – *Drawing Reproduction* covers commonly used methods for reproduction of drawings and points out the importance of good draftmanship to procure good reproductions.

Each lesson contains objectives, readings, review exercises, answers to the exercises and practice drawings. This course was designed for students who have basic drafting skills. It can be used for advanced work and student self-study and evaluation.

3

ARMY CORRESPONDENCE COURSE • ENGINEER SUBCOURSE 131-9

ENGINEERING DRAWING II



6-2

United States Army Engineer School • EDITION 9 (NID 906)

INTRODUCTION

To meet the ever-increasing demand for skilled technical personnel, the Army publishes training manuals for the guidance of all concerned. A basic technical education in the engineering sciences is necessary for the understanding of these manuals. The description of the operation, maintenance and repair of newly developed devices and apparatus, requires the use of engineering drawing. A student who has acquired a clear understanding of the principles of engineering drawing, can proceed to the advanced studies of the technical training manuals.

This subcourse covers subject matter not contained in Subcourse 130, Engineering Drawing I. For most students the successful completion of Subcourse 130 (or its equivalent) is essential and a prerequisite to the beginning of Subcourse 131. The practical exercises are designed so that a student may "learn by doing" through drawing plates which require an application of the principles presented in the attached memorandum.

The subcourse consists of nine lessons and an examination as follows:

Lesson 1. Auxiliary Views.
2. Isometric Drawing.
3. Screws, Bolts, Rivets, and Welds.
4. Detail and Assembly Practices.
5. Intersections and Developments.
6. Machine Drawing.
7. Architectural and Structural Drawing.
8. Map Drawing.
9. Drawing Reproduction.

Examination.

Twenty-eight credit hours are allowed for this subcourse.

You will not be limited to the number of hours you may spend in the solution of any lesson of this subcourse, or the examination. For statistical purposes, however, you are required to enter in the proper space on the answer sheet the number of hours spent on each lesson, including the time in study of the textual material.

Materials furnished:

Drafting kit.

Practice plates: A, D, G. I, K, L, O, and R.

Exercise plates: B, C, E, F, H, J, M, N, P, Q, S, and T.

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The drafting kit (except for the expendable items — pencils, ruby eraser, art gum, sandpaper block, and drafting tape) must be returned after you have been notified in writing that you have successfully completed the subcourse. DO NOT return it before being requested to do so.

The practice plates will enable you to determine for yourself just how well you are progressing. If you feel that you need more practice than provided in the practice exercises, it is suggested that you obtain a suitable sketch pad (9" x 12") from an art supply or stationery store. The practice plates are for your own use only. DO NOT send them with your answer sheets.

Lesson answer sheets are bound in reverse order at the back of this book. Be sure that the lesson number on the answer sheet is the same as the lesson you are working on. The examination will be sent to you after you have successfully completed all the lessons.

13

LESSON 1

AUXILIARY VIEWS

CREDIT HOURS ----------- 3

TEXT ASSIGNMENT ------ Attached memorandum.

MATERIALS REQUIRED ---- Drafting kit and plates A, B, C.

LESSON OBJECTIVE ------ To teach you the use of auxiliary planes of projection to show the true size and shape of plane surfaces.

SUGGESTIONS ----------- Study the attached memorandum and pay careful attention to the figures accompanying the text.
After completion of the practice work and checking your results, restudy points you missed before proceeding with work to be submitted for grading.

ATTACHED MEMORANDUM

1. REQUIREMENTS FOR AUXILIARY VIEWS

Some objects have surface areas which are NOT parallel to any one of the three principal planes of projection. Such surfaces are either inclined or oblique and cannot be projected in their true shape or size on any one of the principal planes of projection. When this occurs, the true shape and size of the inclined plane can only be projected on an **auxiliary plane** placed parallel to it. If the inclined plane is **perpendicular** to one of the principal planes of projection, the auxiliary plane is visualized as "hinged" and therefore "related" to that principal plane. The inclined surface shows as an edge or single straight line on the plane to which it is perpendicular. The hinged intersection of the auxiliary plane with the principal plane to which it is related is called a **reference line.** Reference lines are drawn as light construction lines, and the auxiliary plane **is revolved** into the plane of the drawing paper about the hinged reference line. The view on the auxiliary plane is called a **single auxiliary view** (block F, fig 1-1).

2. TYPES OF AUXILIARY VIEWS

a. **Elevations.** The auxiliary view of an object's surface which is perpendicular only to the horizontal plane (top view), is hinged and related to the top view and is called an auxiliary **elevation.** They may be right, left, front or rear auxiliary elevations depending upon the point of view.

b. Right or left. The auxiliary view of an object's surface which is perpendicular only to the vertical plane (front view), is hinged and related to the front view and is called a **right** or **left** auxiliary view. A side view may be substituted for the top view as shown in figure 1-1.

c. Front or rear. The auxiliary view of an object's surface which is perpendicular only to the profile plane (side view), is hinged and related to the side view and is called a **front** or **rear** auxiliary view.

d. Double. If an object has a surface which is inclined to all three principal planes of projection, and does not project as an edge on any

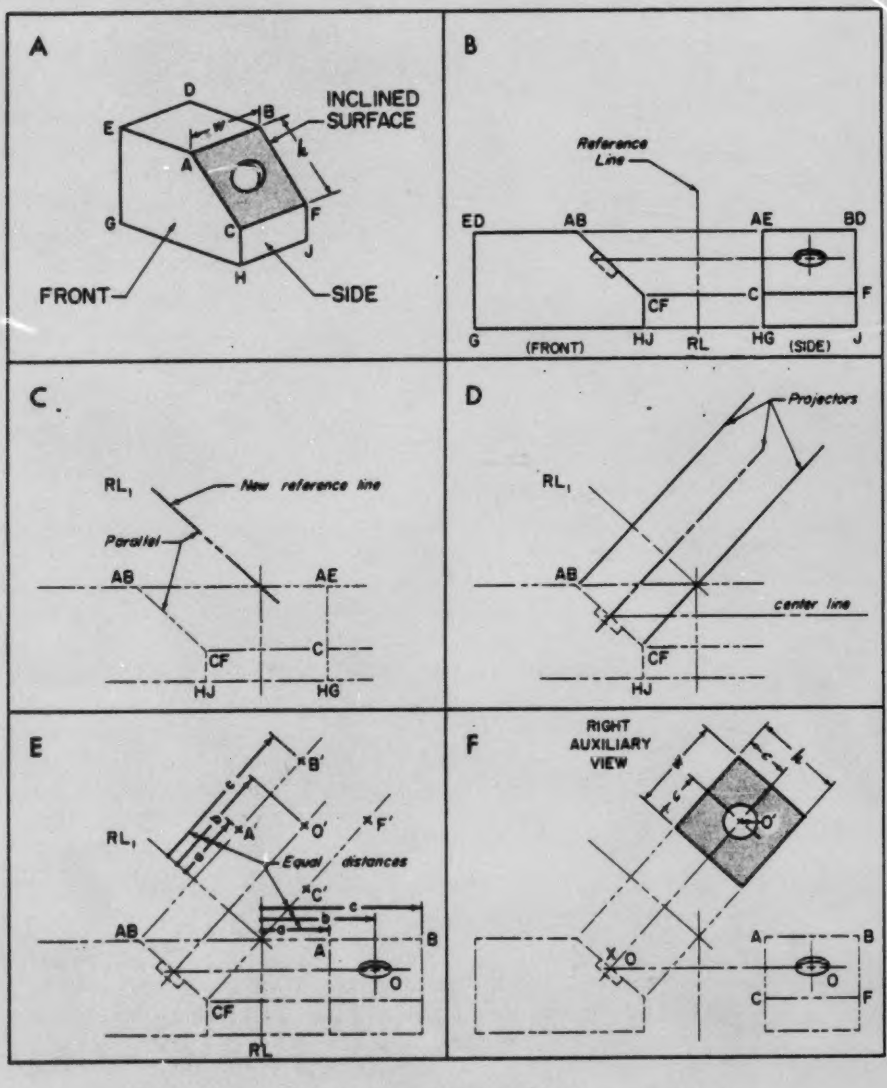
A
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Figure 1-1. Procedure for drawing single auxiliary views.

principal plane, its true size and shape cannot be projected on a single auxiliary plane. Such a surface is called an **oblique** surface, and it projects as an edge on a single auxiliary plane. Its true size and shape can only be projected on a second or double auxiliary plane. This projection on the double auxiliary plane is called a **double auxiliary view** (block F, fig 1-2).

3. PROJECTION TO SINGLE AUXILIARY VIEWS

Figure 1-1 illustrates the procedure for drawing a right auxiliary view. The procedure, typical of the procedure for drawing all single auxiliary views, is as follows:

a. **Principal view.** Select two related principal views, one of which will show the inclined surface as an edge. In figure 1-1, the inclined surface appears on edge in the front view and the front and side views are the related views selected. Draw the two related orthographic views (separated by the reference line RL as in block B, fig 1-1) located so as to allow space on the drawing for the auxiliary view.

b. **Reference lines.** Draw a reference line RL_1 (block C, fig 1-1) which is parallel to the edge of the inclined surface and at a convenient distance from the principal view. This new reference line (RL_1) forms the base from which the inclined plane is projected into the auxiliary. Just as the reference line RL separates the front and side views, reference line RL_1 will separate the front and right auxiliary views. Both reference lines represent the intersection of two perpendicular projection planes, and are visualized as hinged connections.

c. **Point projection.** Draw projectors **perpendicular to RL_1** from the end points AB and CF of the edge of the inclined surface in the principal (front) view, and extend these lines a reasonable distance (block D, fig 1-1). Also draw projector of centerline perpendicular to RL_1 at point of intersection on edge of inclined surface.

d. **Transferring measurements.** With the dividers, transfer points A′, B′, C′, F′, and O′ (measurements a, b, and c) from the side view to the right auxiliary view as illustrated in block E, figure 1-1. Note that the depth of an object is measured perpendicular to the frontal plane, and that the side and auxiliary planes are both perpendicular to the frontal plane. Thus the perpendicular distance from any point in the side view to RL is exactly equal to the distance of the same point in the auxiliary view measured from RL_1 along a projector drawn perpendicular to RL_1.

> It is to be noted that the transfer of measurements by this method, between the two principal views, actually develops the true shape and size of the inclined surface. It is NOT necessary to visualize the shape and size beforehand; the projections develop true shape and size. A scale may also be used to transfer measurements (architect's 16 scale being preferable).

From the above, it is seen that the method of projecting the true image of the inclined surface to an auxiliary plane is the same as projecting an image of an object to one of the principal planes.

e. **Completing view.** After all the principal points of the inclined surface have been located in the auxiliary view, connect the points with visible edge lines (block F, fig 1-1), thus showing the true size and shape of the inclined surface. To complete the auxiliary view, set bow compass to the measurement OX on the edge of the inclined surface (front view), and using center O′ draw circle on the auxiliary view.

> Note in blocks B, E, and F, figure 1-1, that the inclined surface ABFC appears as distorted or foreshortened in the side view, as an edge in the front view and in its true size and shape in the right auxiliary view. **The auxiliary view shows the inclined surface only and all other features of the object are omitted.**

4. PROJECTION TO DOUBLE AUXILIARY VIEWS

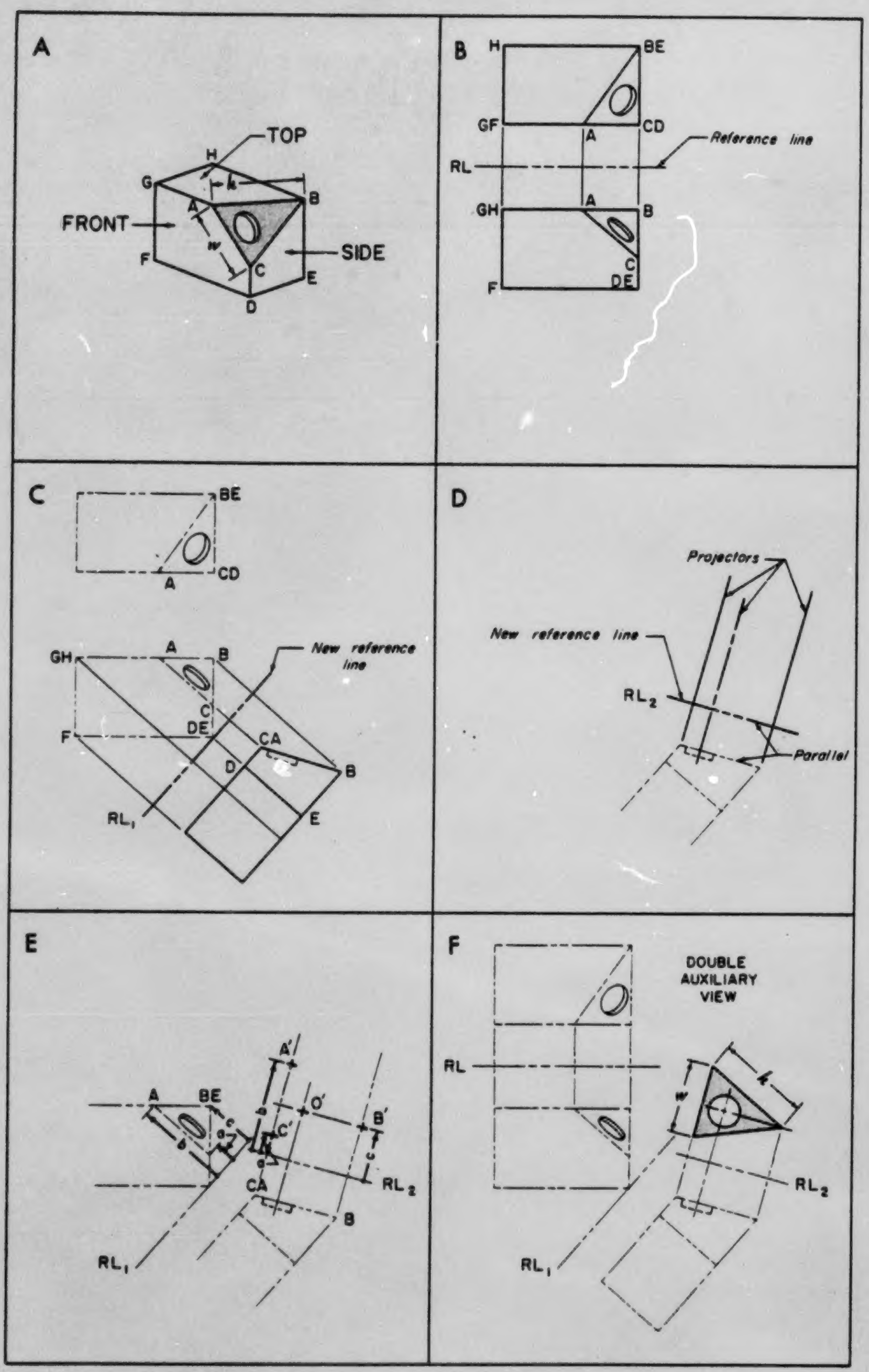
An oblique surface was defined (par 2d, above) as a surface which does not project as an edge on any principal view. Two operations are required to find its true shape and size. First, it is necessary to present the oblique surface as an edge on a preliminary (single) auxiliary view, and second, project the final (double) auxiliary view from this new view. A single auxiliary is always projected from a principal view; a double auxiliary is always projected from a single auxiliary. Figure 1-2 illustrates the procedure for drawing a double auxiliary view.

a. **Related views.** Select two related principal views one of which will show a line on the oblique plane in its true length. Draw the two related orthographic views separated by a reference line RL, similar to the procedure for projection of single auxiliary views given in paragraph 3a above. In figure 1-2, the front and side views are the related views selected. Note that the line AC (top view) lies on the oblique plane and is parallel to RL. AC therefore projects in its true length in the front view (block B, fig 1-2).

b. **Preliminary auxiliary view.** After the front view has been drawn, showing AC in its true length, draw the reference line RL_1 perpendicular to AC (block C, fig 1-2). Project points A, B, C, D, and E into the preliminary auxiliary, locating their positions on their projectors, using the dividers (or scale), by taking the corresponding depths in the top view and transferring these to the auxiliary. Complete the preliminary auxiliary view as in block C, figure 1-2. Note that the line CA-B now projects the oblique plane as an edge on the preliminary auxiliary view.

c. **Reference line for double auxiliary.** Draw a reference line RL_2 parallel to the edge of the oblique surface. Extend projectors perpendicular to RL_2 from the points CA and B, a reasonable distance as in block D, figure 1-2. Also draw projector of centerline perpendicular to RL_2 at point of intersection on edge of oblique surface.

d. **Transferring measurements.** Project points A′, B′, C′, and O′ into the final double auxiliary view, locating their positions on their projectors, by taking the corresponding measurements in the preliminary auxiliary and transferring these to the double auxiliary (block E, fig 1-2).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Projectors
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Parallel
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O'
B'
C'
CA
RL2
B
RL1
F
DOUBLE AUXILIARY VIEW
RL
w
h
RL2
RL1

Figure 1-2. Procedure for drawing double auxiliary or oblique views.

11

e. Completing view. The procedure for completing the double auxiliary, showing the true shape and size of an oblique surface, is the same as that for a single auxiliary. After all the points have been located, connect the points with visible edge lines and complete the circle for the hole as in block F, figure 1-2.

5. PARTIAL AUXILIARY VIEWS

A view that does not show a complete projection is called a **partial view.** When the inclined surface of an object is projected on an auxiliary plane, the inclined surface appears in its true shape and size but the other surfaces are foreshortened. Foreshortened details are omitted from auxiliary views because they are shown in their true shape and size in the principal views. Partial auxiliary views may be used to represent shape and details of an inclined surface only. A partial auxiliary view decreases drawing time and clarifies the true shape description of an inclined surface by eliminating unnecessary lines and details. For example,

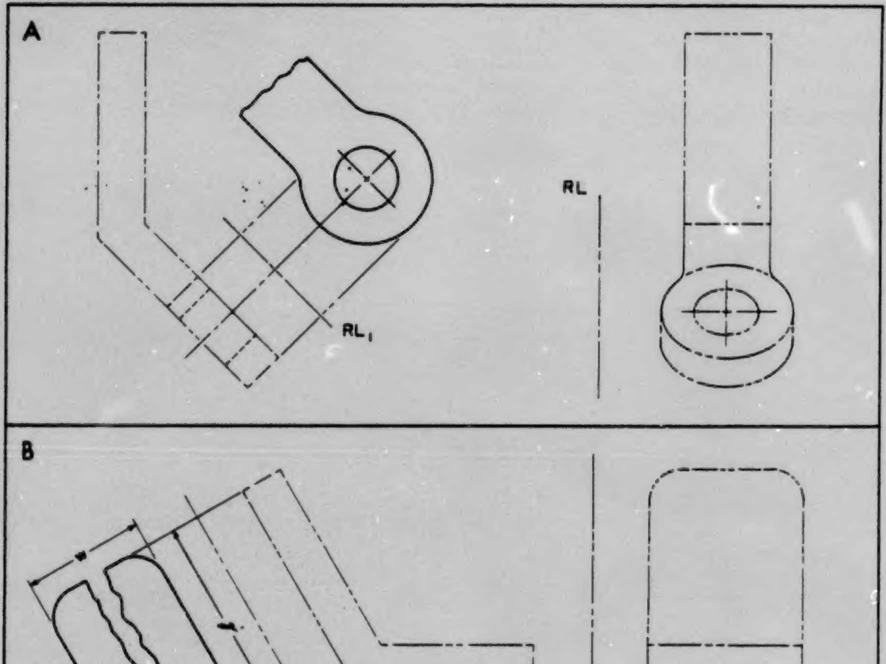


Figure 1-3. Partial auxiliary views.

notice that the partial auxiliary in block A, figure 1-3, gives all the essential information concerning the inclined surface, and yet is much clearer and takes less time to draw than to project a complete auxiliary view. Block B, figure 1-3, shows how a section of an auxiliary might be broken out to save space on a drawing, or when the size of the sheet limits the space available.

6. DIMENSIONS

All dimensions should be shown on a view where their true length appears. The basic reason for using auxiliary views is "to present the true size and shape of inclined or oblique surfaces so that they can be dimensioned". Thus the dimensions of such surfaces should be shown only on an auxiliary view, and are drawn in accordance with the general rules for dimensions (Engineering Drawing I). On figures 1-1 and 1-2 the inclined and oblique surfaces are dimensioned in the auxiliary views as shown in block F of each figure. Notice that the dimensioning of the auxiliary view in block B, figure 1-3, includes the broken out section.

7. PRACTICE WORK

Here is an opportunity for you to determine for yourself just how well you have learned the material in this lesson. Work the following exercises, then check your answers with the solutions at the back of this booklet. Wherever you find that you have missed the answer, refer to the reference given and restudy the text material, and also check your plate so that you will understand just where you went wrong. This practice work will help prevent similar mistakes in later work. This is a self-test only. DO NOT send in your answers to these exercises.

First Requirement. Exercise 1 is designed to give you practice in drawing auxiliary views.

1. **Plate A** shows two views each of four different objects. In each case an auxiliary view is required to complete the representation of the object. You are required to draw the missing view according to the title of each frame. Use a 2H pencil for all visible edges, a 4H pencil for hidden lines and a 6H pencil for construction lines. Show where you would place dimensions. DO NOT submit this practice sheet.

Second requirement. The following five exercises are true or false. If you believe a statement is true check "T", if false or only partly true check "F".

2. An auxiliary view of an object is used to show the true size of an inclined surface. T F
3. An inclined surface is one that is not parallel to any one of the three principal planes of projection. T F
4. An oblique surface is one that is not parallel to any one of the three principal planes of projection but is perpendicular to one of them. T F

5. A reference line for an auxiliary view is drawn perpendicular to the hinged edge where two projection planes intersect. T F

6. The auxiliary view of a surface which is perpendicular to the horizontal plane is called a horizontal auxiliary view. T F

Third requirement. Solve multiple choice exercises 7 through 15 to determine how clearly you understand the subject of auxiliary views.

7. A single auxiliary view is drawn as though hinged to, and projected from a principal view in which the:
   a. inclined plane appears as an edge
   b. plane of projection is parallel to a principal plane
   c. inclined surface appears at a reduced size
   d. inclined surface is parallel to two of the principal axes

8. The true projection of an inclined surface on an auxiliary view is most useful to the builder because it shows:
   a. one of the principal dimensions on edge
   b. all curved surfaces as straight lines
   c. the true size and shape of the inclined surface
   d. which side of the object is the front elevation

9. If an inclined surface of an object shows in the front view as a single straight line, its auxiliary view is called a:
   a. front or rear auxiliary view
   b. right or left auxiliary view
   c. auxiliary elevation
   d. double auxiliary view

10. Reference lines drawn on projected drawings represent the:
    a. intersection of two parallel planes
    b. datum line for marking dimensions
    c. intersection of two perpendicular axes
    d. intersection of perpendicular projection planes

11. A double auxiliary view is always projected from a:
    a. front view
    b. top view
    c. single auxiliary
    d. final auxiliary

12. How many additional views are required to find the true shape and size of an oblique surface if two principal views are given?
    a. one
    b. two
    c. three
    d. five

13. The reference line RL_2 in double auxiliary projection separates the:
    a. two principal related views
    b. parallel projectors
    c. preliminary and final auxiliary views
    d. perpendicular projectors

14. Foreshortened details of an object are not shown in an auxiliary view because:
    a. a broken or partial view would be required
    b. it would require too many hidden lines to be shown
    c. the dimensions would have two different scales
    d. their true size and shape is shown on a principal view

15. In dimensioning auxiliary views a draftsman should:
    a. make all dimension lines parallel to an inclined surface
    b. use dotted lines to indicate auxiliary dimensions
    c. draw the dimension lines oblique to the inclined surface
    d. follow the general rules for drawing dimensions

EXERCISES

First requirement. Exercises 1 and 2 provide an opportunity for you to show just how well you can present auxiliary views. Follow the instructions carefully; your work will be graded on correctness and completeness of views as well as proper line weights and neatness.

1.

Plate B shows two views of a connector strip which do not completely describe the true shape and size of the two end portions of the object. Complete plate B by drawing the true size and shape of the two end portions of the connector strip on two auxiliary views (one for each end). Note the scale as given. Fully dimension the auxiliary views. DO NOT erase construction lines. Use 2H, 4H, and 6H pencils in the same manner as in practice exercise 1.

2.

Figure 1-4 shows the isometric drawing of an angle brace. The front and side orthographic views of this angle brace are already shown on **Plate C.** Complete plate C by drawing the auxiliary view required to show the true shape and size of the bottom flange of the angle brace. Because of the limited space, only a partial auxiliary view can be drawn; scale used is full size 12″ = 1′-0″. Show dimensions of the inclined surface (bottom flange) on the partial auxiliary view. DO NOT erase construction lines.

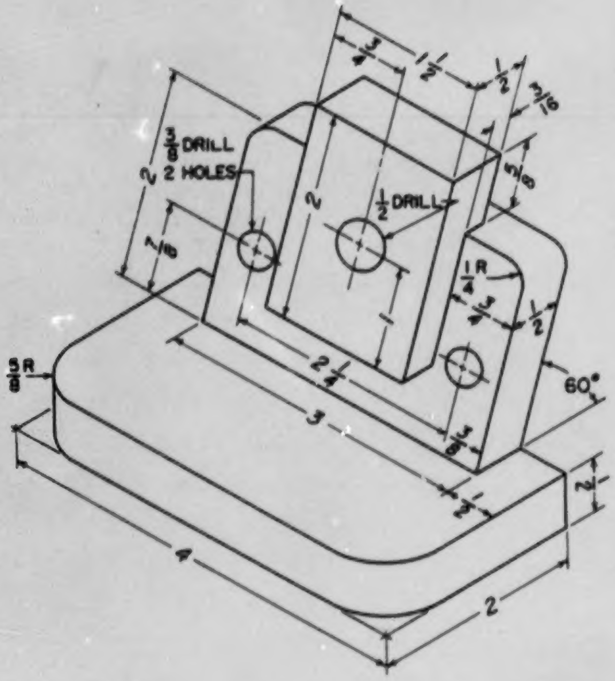


Figure 1-4. For use with exercise 2.

Second requirement. Exercises 3 through 12 are designed to test your understanding of the principles presented in the attached memorandum as applied to the completion of plates B and C. Each of these exercises has four choices with only ONE BEST answer. Select the choice you believe is best. Then turn to the answer sheet and mark an X through the letter representing that choice. (Answer sheets are bound in **reverse order** at the back of this book.)

3.

Two auxiliary views are required to fully describe the connector strip in plate B because the object has:

a. more than six sides

b. no identical or symmetrical sides

c. internal features lying in a plane parallel to one of the three principal projection planes

d. two inclined surfaces which are not parallel to any one of the three principal planes of projection

4.

The two auxiliary views required to complete **plate B** are called:

a. front and rear auxiliary views
b. right rear and left rear auxiliary elevations
c. right and left auxiliary views
d. double auxiliary views

5.

The auxiliary view required to complete **plate C** is called a:

a. right auxiliary view
b. bottom auxiliary view
c. rear auxiliary view
d. partial elevation

6.

In completing **plate B**, the first step in the procedure of projecting the required auxiliary was to draw:

a. the projectors perpendicular to the edge view
b. reference lines RL separating the two principal views
c. the rear view of the connector strip
d. reference lines RL_1 parallel to each inclined surface

7.

Only one auxiliary view is necessary to fully describe the angle brace of **plate C** because:

a. it has only one inclined surface
b. its two inclined surfaces are parallel and appear on edge in a principal view
c. only one auxiliary view can be crowded on the drawing
d. a double auxiliary view would require too much time to draw

8.

The broken lines shown on the auxiliary view of **plate C** are used to:

a. confuse unauthorized persons from understanding the view
b. save material in manufacture of the object
c. save manufacturing time by eliminating a portion of the object
d. save drawing time and also because space is limited

9.

An auxiliary view of an object with a portion broken out as in the auxiliary view of **plate C** is called a:

a. single auxiliary view
b. partial auxiliary view
c. half tone view
d. half auxiliary view

10.

The side view of the angle brace (fig 1-4) was selected as one of the principal related views on plate C for the following reason:

a. it shows the inclined bottom flange on edge

b. it requires less space than the top view

c. only one auxiliary view is necessary

d. side views are always projected with front views

11.

On which view of the angle brace (plate C) should the thickness of the bottom flange be shown?

a. isometric	c. side
b. auxiliary	d. front

12.

All dimensions of the auxiliary views on plates B and C should be drawn in accordance with:

a. their relation to other views

b. measurements from reference line RL

c. corresponding depths in the preliminary auxiliary

d. the general rules for dimensions

LESSON 2

ISOMETRIC DRAWING

CREDIT HOURS __________3

TEXT ASSIGNMENT ______Attached memorandum.

MATERIALS REQUIRED ______Drafting kit and plates D, E, F.

LESSON OBJECTIVE ______To teach you how to make isometric drawings and to acquaint you with their pictorial value to a nontechnical audience.

SUGGESTIONS __________Refer to the suggestions made for lesson 1.

ATTACHED MEMORANDUM

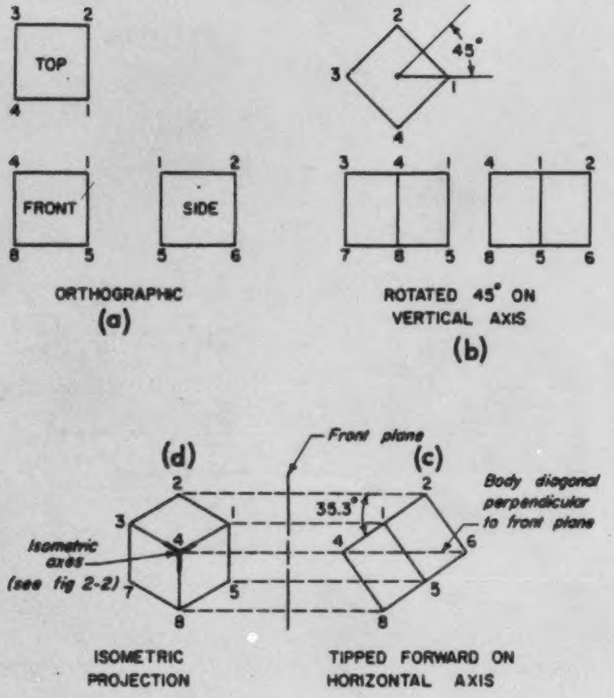
1. PICTORIAL DRAWING

It is easier for nontechnical persons to visualize an object if its features can be shown in a single view. To represent a three dimensional object approximately as it appears to the eye, the draftsman frequently uses a single plane projection which shows the external features only. Such a representation is called a **pictorial drawing.** Perspective drawing, which shows an object as it actually appears to the eye, is largely used in architectural drawing but has the disadvantage that measurements to scale cannot be taken from the drawing. To obtain a pictorial effect and to obtain the advantage of being able to measure dimensions to scale, the isometric drawing is most adaptable. It can be drawn quickly, either freehand or with instruments, and it can be dimensioned directly by use of architects' or engineers' scales.

2. ISOMETRIC PROJECTION

Before the draftsman can develop isometric drawings, it is first necessary to understand isometric projection. This type of projection is made as though viewing the object through a single projection plane, the projection lines being parallel to each other and perpendicular to the projection plane. The object is oriented so that each one of its three principal dimensions are inclined at the same angle to the projection plane, thus exposing three sides in a single view. This is called **isometric projection.**

An excellent example is the isometric projection of a cube. The cube in position a, figure 2-1, is first turned 45° about its vertical axis as in position b.


3
2
TOP
4
1
4
1
FRONT
8
5
1
2
SIDE
5
6
2
45°
3
1
4
3
4
1
4
1
2
7
8
5
8
5
6
(d)
Front plane
(c)
2
3
1
Isometric axes (see fig 2-2)
4
7
5
8
2
35.3°
1
Body diagonal perpendicular to front plane
4
6
5
8

ORTHOGRAPHIC
(a)

ROTATED 45° ON
VERTICAL AXIS
(b)

ISOMETRIC
PROJECTION

TIPPED FORWARD ON
HORIZONTAL AXIS

Figure 2-1. Isometric projection of a cube.

Notice that the front and side orthographic views (position a) are each turned 45° in the horizontal plane, thus showing three vertical faces of the cube in position b.

The cube (right elevation) is then tipped toward the plane of projection as in c until all three of its principal dimensions (edges 4-8, 4-3, and 4-1) are equally foreshortened, thus exposing three faces as in position d. The front view in this position is now an isometric projection of the cube.

Notice that the cube is tipped forward until the body diagonal through 4 (c, fig 2-1) is perpendicular to the front plane. This makes the top face slope approximately 35.3°.

a. Isometric axes. The point where the three principal dimensions of an object, height, width and depth (such as 4-8, 4-3, and 4-1, view d in figure 2-1) converge is called their point of origin, "O". These are called the isometric axes. The angle between each pair of axes is always 120° as in figure 2-2.

b. Isometric lines and planes. Since the projection lines are parallel to each other and perpendicular to the projection plane, the projections of the edges of a rectangular object (such as the cube) will be parallel to an isometric axis. Any line whose projection is thus parallel to an

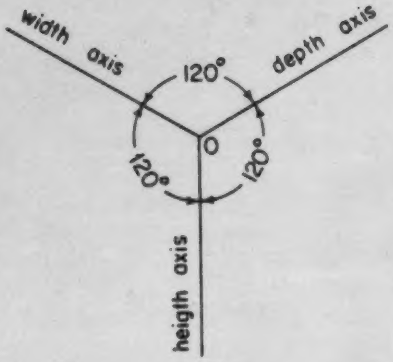

width axis
depth axis
heigth axis
120°
120°
120°
0

Figure 2-2. Isometric axes.

isometric axis is called an isometric line. All other lines which do not project parallel to one of the isometric axes are called **nonisometric lines.** The faces of an object parallel to the isometric axes and all planes parallel to them are identified as **isometric planes.**

3. ISOMETRIC DRAWING

An **isometric drawing** resembles an isometric projection in all respects except that the foreshortening of lines is disregarded, and all

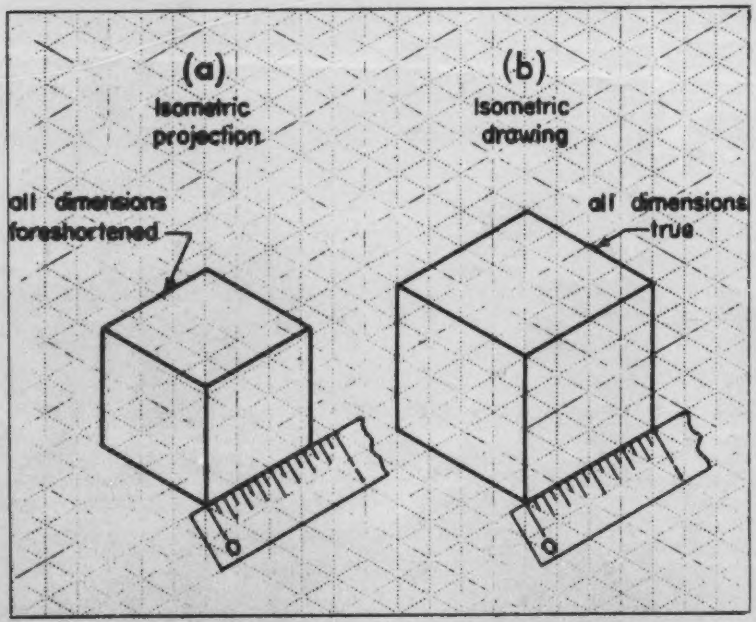

(a)
isometric projection
all dimensions foreshortened
(b)
isometric drawing
all dimensions true
0
0

Figure 2-3. Comparison of isometric projection and isometric drawing.

measurements are drawn true to scale along the isometric axes. Figure 2-3 shows an isometric drawing in comparison with an isometric projection.

> Notice the full size measurement of one inch as compared with the foreshortened (13/16 inch or approximately 81% of true length) dimension.

a. Alternate isometric axes. Usually, it is more expedient to develop an isometric drawing from the lower front corner of the object, point O. In using this procedure, the vertical axis is directed upward from O the point where the other two axes (receding edges, width and depth) intersect the vertical axis, and the receding edges are drawn in the usual manner.

In figure 2-4 the three heavy lines converging at point O, form the **alternate isometric axes.** The width axis is slanted up 30° to the left and the depth axis is slanted up 30° to the right. These receding isometric axes make an angle of 60° with the vertical (height) axis and an angle of 120° with each other. All measurements are drawn to scale along the axes or along isometric lines parallel to the alternate isometric axes.

b. Varied forms of isometric axes. Quite often it is preferable to vary the form of an isometric view so as to show some important detail. This is easily accomplished by changing the position of the isometric axes. Notice however, that the angles between the receding axes never change, although they are placed in varied positions on the drawing sheet (fig 2-5).

c. Locating nonisometric lines. Objects which have several nonisometric lines are generally drawn by the box or offset systems.

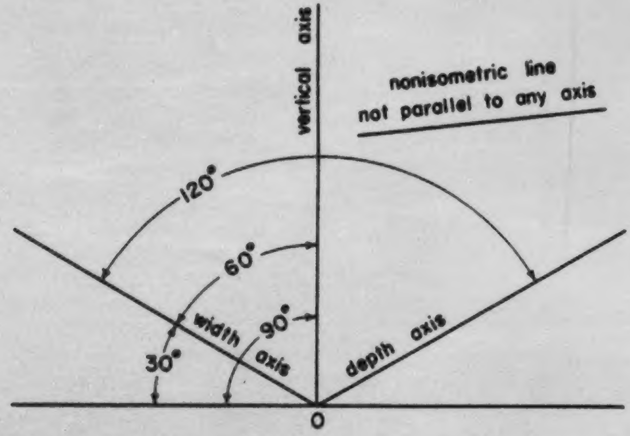
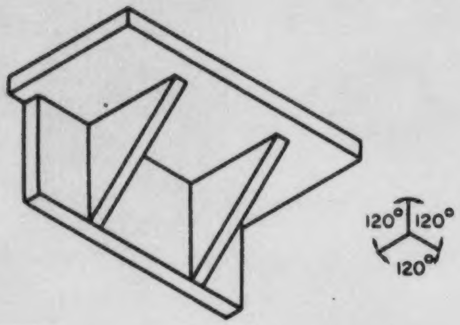


Figure 2-4. Alternate isometric axes.



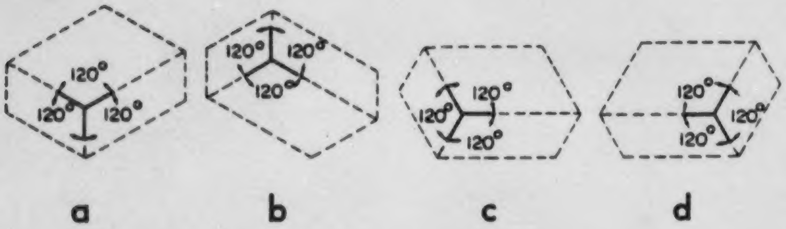

120°
120°
120°
a
120°
120°
120°
b
120°
120°
120°
c
120°
120°
120°
d

Figure 2-5. Diversified positions of isometric axes.

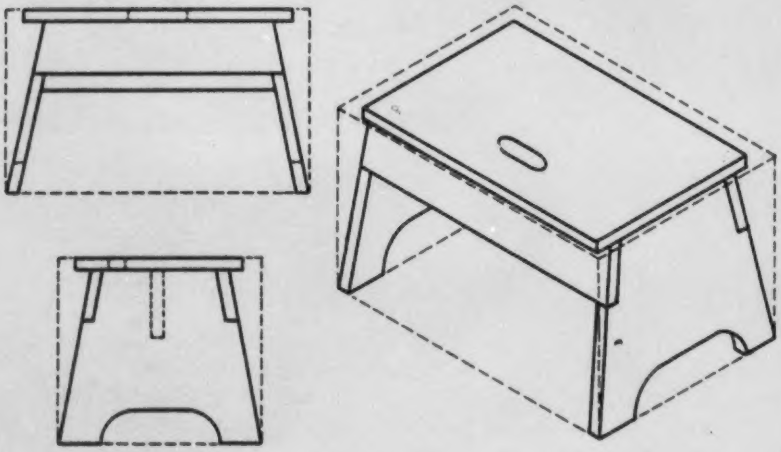


Figure 2-6. Box system of isometric construction.

(1) **Box System.** The object is first drawn in orthographic projection as if contained within a box. The box as a whole is projected in isometric and the configuration of the object is then carefully located by its points of contact with the isometric planes of the box, as in figure 2-6.

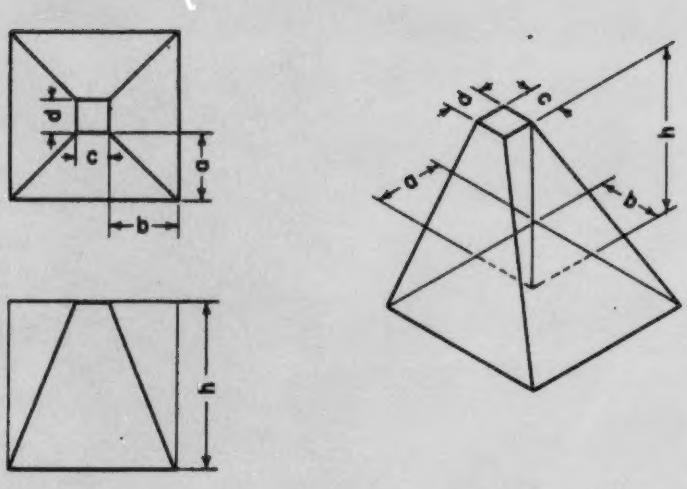


Figure 2-7. Offset system of isometric construction.

(2) Offset system or plotting by coordinates. The offset system (fig 2-7) is used primarily when an object consists of several planes at various angles. In this system, each point of the object is located by plotting its distance from the three axes as though it were a three dimensional coordinate system of height (H), width (W) and depth (D), the dimensions being taken from the orthographic views.

d. Circles. All true circles project as ellipses in an isometric drawing. They are easily drawn by the four center circular arc approximation illustrated in figure 2-8.

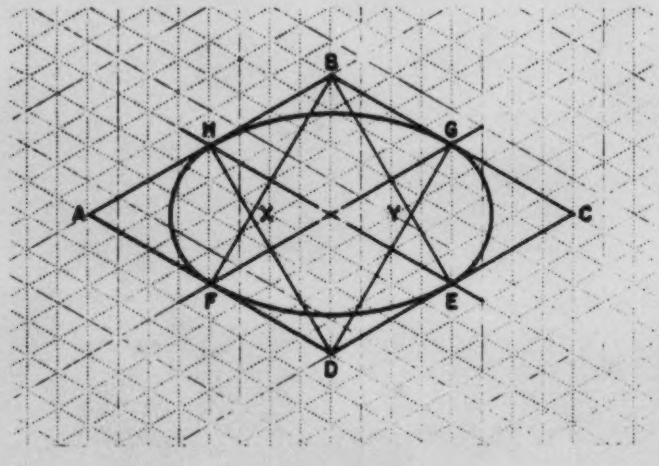


Figure 2-8. Drawing isometric circles and arcs.

(1) Locate center and four sides of the circumscribed square, ABCD. (Note that the circumscribed square is actually a rhombus in isometric construction.)

(2) Draw center lines through the center of the rhombus and parallel to the isometric axes. These center lines intersect at the midpoints (E, F, G, and H) of the sides.

(3) Draw lines from vertices of the two largest angles of the rhombus to midpoints of the opposite sides BE, BF, DG, and DH. These construction lines intersect in points X and Y.

(4) With points B and D as centers and radius BE draw arcs EF and GH.

(5) With points X and Y as centers and radius XH draw arcs FH and EG.

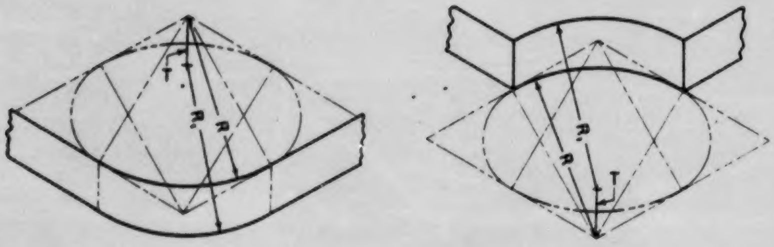


Figure 2-9. Isometric rounding of corners.

To draw any arc of a circle, such as the rounding of corners which occurs most frequently, project as much of the four-center construction as is necessary. To account for thickness (T) drop perpendiculars to establish centers, as shown in figure 2-9.

e. **Hidden lines.** Hidden lines are generally omitted in an isometric drawing, unless their use would add to clarity.

f. **Dimension lines.** Dimension lines, extension lines and the lettering of dimensions are drawn parallel to isometric lines.

g. **Isometric paper.** Sheets of paper ruled with isometric lines (30° receding lines) are most suitable for making isometric drawings. Their use saves a large amount of construction and assures accuracy. Figures 2-3, and 2-8 are drawn on isometric paper.

4. PRACTICE WORK

This practice work is designed to test your understanding of isometric axes and their use in making isometric drawings. Check your results with the solutions at the back of this booklet. If you have made errors, particularly on your drawings, restudy the attached memorandum and correct your errors before proceeding with the exercises. DO NOT submit your practice work sheet.

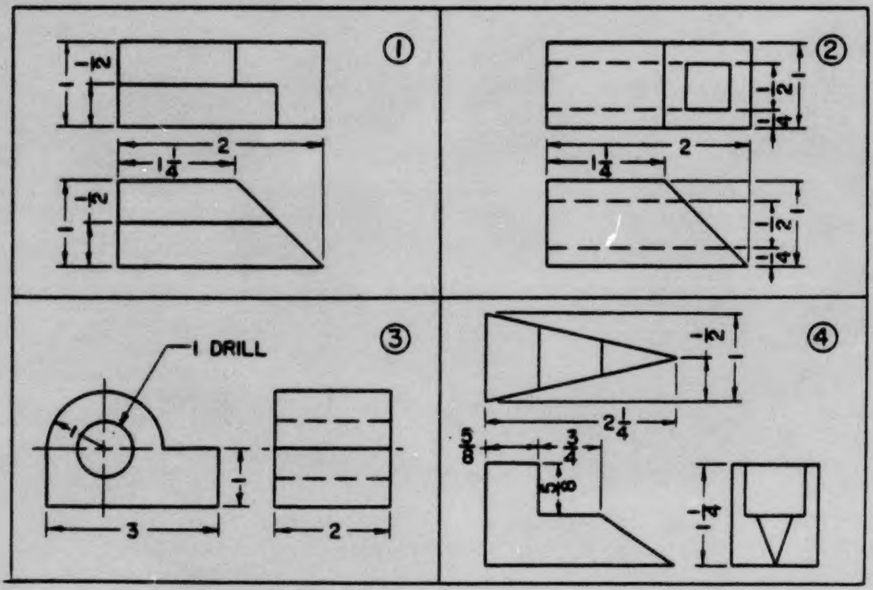


Figure 2-10. For use with practice exercises 1 through 4.

First requirement (exercises 1 through 4). Figure 2-10 shows the orthographic views of four different objects. On **Plate D**, draw the isometric views of each object from the key points numbered 1, 2, 3, and 4 for each exercise; make each isometric drawing of the respective objects full scale. Use drafting instruments for accuracy. Use 6H pencil with sharp cone point for all construction lines, and F pencil for clarity of isometric drawings.

Second requirement. The following six exercises are true or false. If you believe a statement is true check "T", if false or only partly true check "F".

5. The axes used for isometric projection are the same as the axes used for orthographic projection. T F

26

6. Alternate isometric axes are generally used for isometric drawing. T F

7. All dimensions in isometric drawing are reduced to about 81% of their true length. T F

8. Nonisometric lines are lines that cannot be drawn on isometric drawings. T F

9. All true circles on an object appear as ellipses when drawn on isometric drawings. T F

10. Dimensions on isometric drawings can be measured directly with an architect's scale. T F

EXERCISES

First requirement. Exercises 1 and 2 are designed to give you an opportunity to demonstrate your understanding of the principles of isometric drawing. Follow the instructions carefully. Your plate will be graded on layout, completeness, dimensioning, neatness, and accuracy.

1.

Figure 2-11 shows three orthographic views of a hinged catch. On **plate E,** make a full size isometric drawing of the hinged catch; DO NOT show dimensions. Use the given alternate isometric axes and project drawing from point O as designated in figure 2-11. Note that the three holes are the same size and that their isometric ellipses can be constructed at the same time with identical compass settings. Use 6H and F pencils in the same manner as for practice exercises 1 through 4.

2.

Figure 2-12 shows three orthographic views of a swivel block. On **plate F,** make a full size isometric drawing of the swivel block; show principal overall dimensions only. Use the given alternate isometric axes and project drawing from point O as designated in figure 2-12. Note that identical circles project as identical ellipses and can be constructed simultaneously. Use 6H and F pencils, as before; use 4H pencil for dimension lines and HB pencil for lettering.

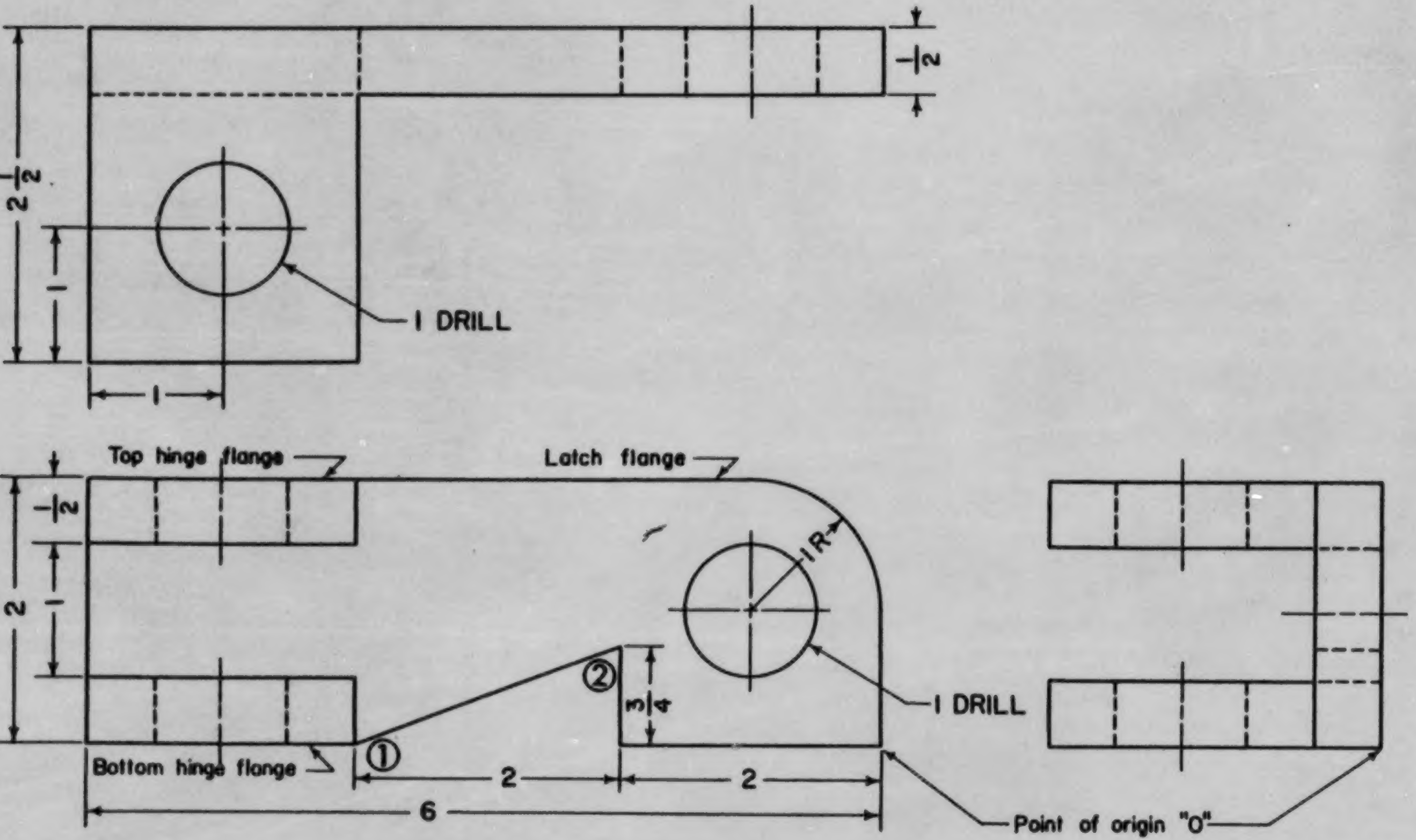

1 DRILL
2½
1
1
½
Top hinge flange
Latch flange
½
2
1
1R
1 DRILL
②
¾
①
Bottom hinge flange
2
2
6
Point of origin "O"

Figure 2-11. For use with exercise 1.

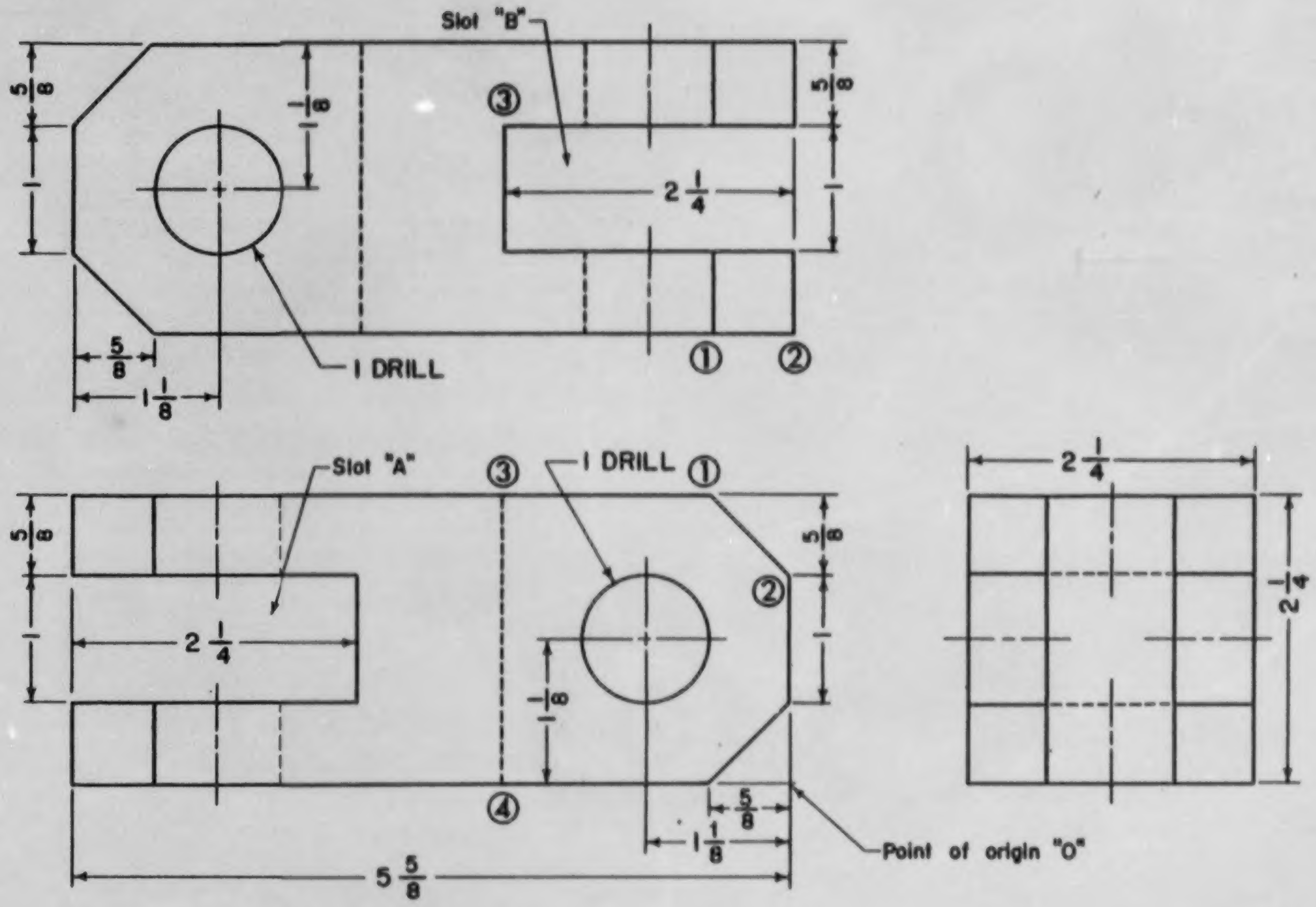

Slot "B"
③
5/8
1 1/8
5/8
1
2 1/4
5/8
1
① ②
5/8
1 1/8
1 DRILL
Slot "A"
③
1 DRILL
①
5/8
1
2 1/4
②
5/8
1
1 1/8
④
5/8
1 1/8
5 5/8
Point of origin "O"
2 1/4
2 1/4

Figure 2-12. For use with exercise 2.

Second requirement. Multiple-choice exercises 3 through 12 are based on the application of the principles of isometric drawing to the completion of plates E and F. In solving these exercises, test your answers against your isometric drawings. This should prove to be an excellent check as to their correctness.

3.

To make isometric drawings such as **plate E** more easily understood it is customary to:

a. use heavy lines for dimension lines
b. omit hidden lines from the drawing
c. omit all nonisometric lines
d. draw all ellipses as true circles

4.

The scale most convenient to be used for drawing **plate E** is:

a. the same as the scale for an isometric projection
b. an ordinary scale reduced by about 19%
c. an ordinary engineer's scale marked 50
d. a standard architect's scale marked 16

5.

If a true isometric projection were made of the hinged catch on **plate E**, it would be:

a. smaller than the isometric drawing
b. the same size as the isometric drawing
c. larger than the isometric drawing
d. any size depending upon the size of the paper

6.

The isometric drawing of the hinged catch of **Plate E** is preferable to an isometric projection because:

a. the isometric scale requires time consuming conversions
b. an isometric drawing shows more details than an isometric projection
c. true dimensions can be measured directly from the drawing
d. isometric projections show no dimensions

7.

A true perspective drawing of the hinged catch of **Plate E** would not be satisfactory to a builder because:

a. its dimensions could NOT be measured directly
b. the perspective is the reverse of the true shape
c. the perspective drawing costs more to produce
d. the builder cannot understand perspective drawings

8.

Referring to the front view of figure 2-11, the line joining points 1 and 2 is located on **plate E** by:

a. plotting each point according to their coordinates
b. considering it as a single point
c. the four-center approximation
d. orthographic projection

9.

Because of its many nonisometric lines the isometric view of the swivel block, **plate F,** is easier to construct by:

a. reversed isometric axes
b. box system
c. nonparallel lines
d. offset system

10.

The hidden line joining points 3 and 4 on the front view figure 2-12, when referred to completed **plate F**:

a. is not shown, because hidden lines are omitted
b. does not appear from the angle at which viewed
c. appears as a foreshortened nonisometric line
d. is a partially visible isometric line parallel to vertical axis

11.

The completed **plate F** shows that the line between the points 3 and 1 on the front view of figure 2-12 is:

a. a hidden line obscured by a visible edge
b. a foreshortened line whose true length is shown on plate F
c. the edge of a plane surface in the horizontal plane
d. a straight line showing its true length on the front view of figure 2-12

12.

The completed isometric drawing of the swivel block on **plate F** shows:

a. one complete ellipse and three partial ellipses
b. two complete ellipses and five partial ellipses
c. three complete ellipses and one partial ellipse
d. five complete ellipses and two partial ellipses

LESSON 3

SCREWS, BOLTS, RIVETS, AND WELDS

CREDIT HOURS ----------- 3

TEXT ASSIGNMENT ------ Attached memorandum.

MATERIALS REQUIRED ---- Drafting kit and plates G, H.

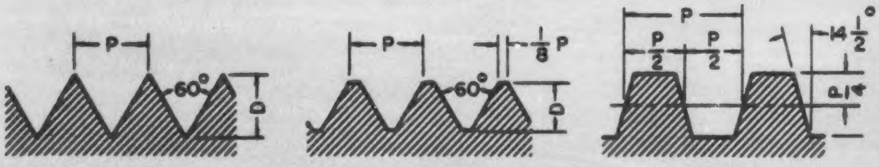
LESSON OBJECTIVE ------ To teach you how to draw common fasteners used to connect assembled parts.

SUGGESTIONS ---------- Refer to the suggestions made for lesson 1.

ATTACHED MEMORANDUM

1. GENERAL REQUIREMENTS

It would be impossible to build any structure or machine out of solid materials. It is necessary to build by joining component parts into larger parts or a complete assembly. In any case the draftsman must be familiar with the methods of fastening the parts together, in some instances as permanent fastenings such as welds and rivets, or as removable connections requiring screws and bolts. The basic forms of such parts and the conventional method of their representation are inherently a part of the graphic language of the draftsman. A complete description of all types of fasteners is beyond the scope of this subcourse. Only a few of the more common types with their representations and some definitions of importance to a draftsman are covered. The descriptions and methods of showing other fasteners can be found in military standard specifications, or in one of the numerous standards handbooks available.



SHARP V AMERICAN STANDARD ACME

Figure 3-1. Types of screw threads.

2. SCREW THREADS

Screw threads are used to restrict or fix the relative motion of two parts or to transmit motion from one part to another. The more common types of threads and their general use are shown in figure 3-1.

Threads may be right or left hand. **Right-hand** threads advance when turned clockwise; a left-hand thread advances when turned counter-clockwise. Left-hand threads are always indicated by LH in the thread specification note; without this note all threads are considered as right-hand.

a. Terminology. Refer to figure 3-2 when studying the following definitions.

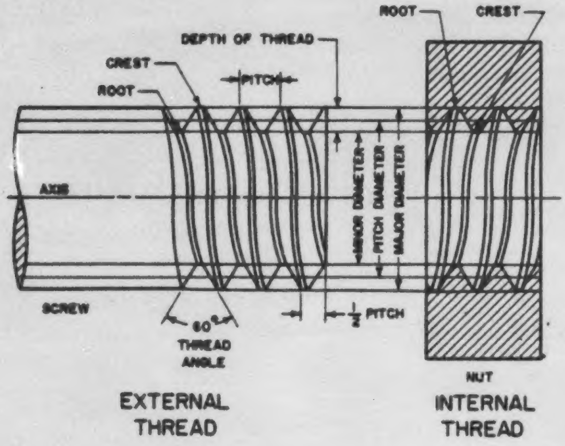

ROOT
CREST
DEPTH OF THREAD
CREST
PITCH
ROOT
AXIS
MINOR DIAMETER
PITCH DIAMETER
MAJOR DIAMETER
SCREW
60°
THREAD ANGLE
½ PITCH
NUT
EXTERNAL THREAD
INTERNAL THREAD

Figure 3-2. Screw-thread definitions.

Axis. The centerline of a screw thread running lengthwise.

Crest. A flat surface on the major diameter of an external thread or on the minor diameter of an internal thread (top of the thread).

Depth. Half the difference of the major and minor diameter or the distance from the crest to the root measured perpendicular to the axis.

External thread. A thread on the outside of an object such as a rod or bolt.

Helix. The "cork-screw" space curve on a cylindrical surface which marks the location of a point moving with uniform angular velocity about the axis and at the same time with uniform linear velocity parallel to the axis.

Internal thread. A thread on the inside of an object such as a nut.

Lead. The distance a point on a helix or screw thread advances parallel to the axis while making one complete turn of the axis (the distance the screw advances in one turn). On a single-thread screw the lead and pitch are identical; on a double-thread screw the lead is twice the pitch; on a triple-thread screw the lead is three times the pitch.

Major diameter. The largest diameter of an internal or external thread.

Minor diameter. The smallest diameter of an internal or external thread.

Pitch. The distance from a point on a screw thread or helix to a corresponding point on the next thread, measured parallel to the axis. On a double-thread screw the pitch is half the lead.

Root. The surface of a thread on the minor diameter of an external thread or on the major diameter of an internal thread (bottom of the thread).

Threads per inch. One inch divided by the pitch.

b. **Thread conventions.** An accurate orthographic representation of any screw thread is impractical. In actual practice they are represented by drawing straight lines and a note is added giving the designers specifications. Thread conventions are classified as semiconventional or symbolic.

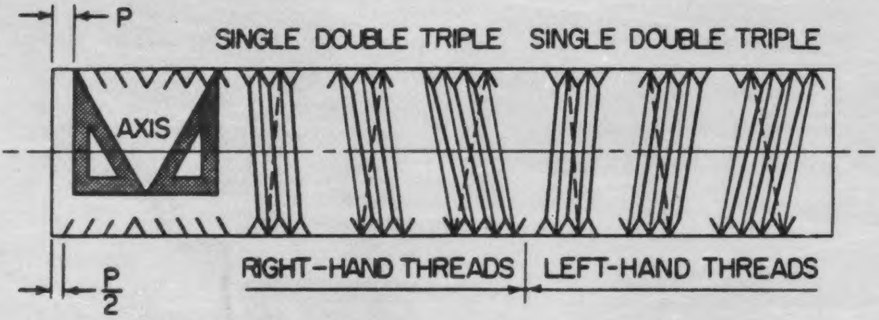


Figure 3-3. Drawing semiconventional threads.

(1) **Semiconventional representation.** Refer to figure 3-3 when studying the following procedure for drawing semiconventional threads.

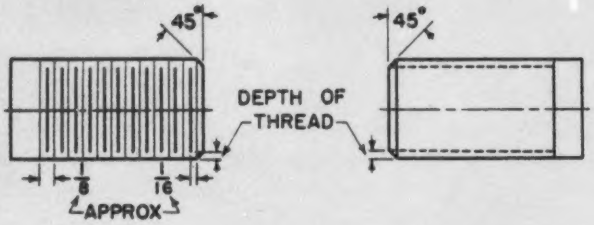
Step 1. Draw the centerline and lines parallel to it, which locate the major diameter of the threads.

Step 2. Mark off pitch distances on upper (major diameter) line for the distance of all threads.

Step 3. On lower (major diameter) line mark one measurement of ½ pitch, then continue marking off pitch distances for the rest of the threads as above.

Step 4. From each point marked on upper and lower lines draw short lines, sloping 60° to the right and left, which form crests and roots of the threads.

Step 5. Connect crests and roots of the threads with solid straight lines to complete threads. Notice that crest lines are not parallel to root lines. Single and triple threads have a root opposite a crest. Double threads have a root opposite a root. The lines of step 5 slope to the left for right-hand external and left-hand internal threads; to the right for left-hand external or right-hand internal threads. The dotted lines of figure 3-3 which indicate the thread on the reverse side of the object are omitted on the actual drawing.



REGULAR SYMBOL

SIMPLIFIED SYMBOL

Figure 3-4. Drawing regular and simplified thread symbols.

(2) **Symbolic representation.** Threads of less than 1-inch diameter (drawing size) may be shown by **regular** or **simplified** thread symbols as shown in figure 3-4. Notice that both omit the V profile.

The **regular symbol** shows the crest of the thread as long thin lines and the roots by shorter heavier lines. These lines are simply spaced, by eye or scale, to look well and need not be related to the actual pitch of the thread.

The **simplified symbol** omits the crest and root lines and shows the approximate depth of the thread by dotted lines indicating the threaded portion. Although not as descriptive as the regular symbol, it is preferred for detail drawings because of being easier to draw and the resultant savings in time.

c. **Specification note.** As stated before, in addition to the thread conventions, the designer's specifications are given in a note. The format, or order of the specification note, is in accordance with accepted standards of which there are three: the American or National (designated as N), the Society of Automotive Engineers, SAE (designated as EF), and the International Organization for Standardization (designated as UN). Only the American standard is covered here; the others are described completely in military standard specifications or standards handbooks. The principal elements are thread series and screw-thread fits.

(1) **Thread series.** The American standard lists five thread series: **coarse** (NC), recommended for general use, includes 12 numbered sizes below ¼ inch; **fine** (NF), has more threads per inch and is used where ease of assembly and resistance to vibration are requisite, includes 13 numbered sizes below ¼ inch; **8-pitch** (8N) eight threads per inch, 1" to 6" dia, used primarily on bolts for high-pressure pipe flanges or cylinder and boiler heads, and similar fastenings against pressure; **12-pitch** (12N), twelve threads per inch, ½" to 6" dia, used widely in machine construction requiring thin parts; and **16-pitch** (16N) sixteen threads per inch, ¾" to 4" dia, used on such items as adjusting collars and bearings retainers. See table I.

TABLE I. *American National Course (NC) and National Fine (NF) Series.*

Number of threads per inch

Size major diameter	NC Series	NF Series	Size major diameter	NC Series	NF Series
0	—	80	9/16	12	18
1	64	72	⅝	11	18
2	56	64	¾	10	16
3	48	56	⅞	9	14
4	40	48	1	8	14
5	40	44	1⅛	7	12
6	32	40	1¼	7	12
8	32	36	1⅜	6	12
10	24	32	1½	6	12
12	24	28	1¾	5	
¼	20	28	2	4½	
5/16	18	24	2¼	4½	
⅜	16	24	2½	4	
7/16	14	20	2¾	4	
½	13	20	3	4	
			3¼	4	
			3½	4	
			3¾	4	
			4	4	

Note: Number 13 size NF series, not given.

(2) **Screw-thread fits.** Four types of screw-thread fits have been standardized:

Class I. For rapid assembly and where some shake play is not objectionable.

Class II. Standard commercial where interchangeability is essential.

Class III. High quality commercial required for precision work.

Class IV. Where selected fit is required.

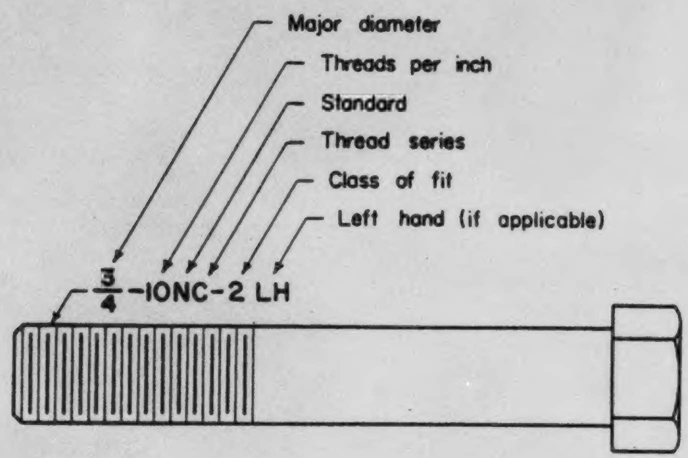

Major diameter
Threads per inch
Standard
Thread series
Class of fit
Left hand (if applicable)
3/4-10NC-2 LH

Figure 3-5. Thread specification note.

Figure 3-5 indicates the order of the specification note and explains its interpretation.

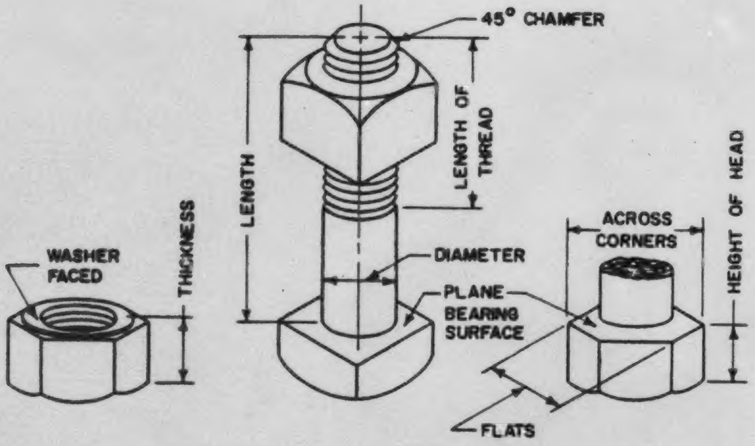

45° CHAMFER
LENGTH
LENGTH OF THREAD
WASHER FACED
THICKNESS
DIAMETER
PLANE BEARING SURFACE
ACROSS CORNERS
HEIGHT OF HEAD
FLATS

Figure 3-6. Bolt information.

3. BOLTS AND NUTS

In general, data concerning bolt dimensions is obtained from standard tables. However, bolts and nuts are seldom shown on detail drawings, and on assembly drawings where they are encountered most frequently approximate dimensions are adequate.

a. Data and terminology. Refer to figure 3-6 when studying the following information concerning bolts and nuts.

Series. Bolts are classed in three series: regular — recommended for general use, heavy — designed to meet requirements for greater surface, and light — smaller across flats than the regular they are designed to save material and weight.

Finish. Bolts may be unfinished, semifinished, or finished. Unfinished bolts, except for threads, are made by forging or rolling and are not machined on any surface. On semifinished or finished bolts, the surface under the nut or bolt head may be machine finished to provide a washer-faced bearing surface. Finished bolts are machined all over for accuracy or to improve their appearance.

Diameter. The shaft size.

Length. Bolts lengths are dimensioned as the distance under the head to the end of the bolt.

Thread length. This is related to the diameter and bolt length. In general, bolts are threaded a distance of 1½ times the diameter plus ⅛ inch. Short bolts, where the formula cannot apply, are threaded full length. On the thread end, bolts are chamfered at an angle of 45° to the depth of the thread.

Washer face. The diameter of the machined surface forming the washer face is equal to the distance across flats. The thickness is 1/64 inch for both bolt heads and nuts, and is always included in the height of the head or thickness of the nut.

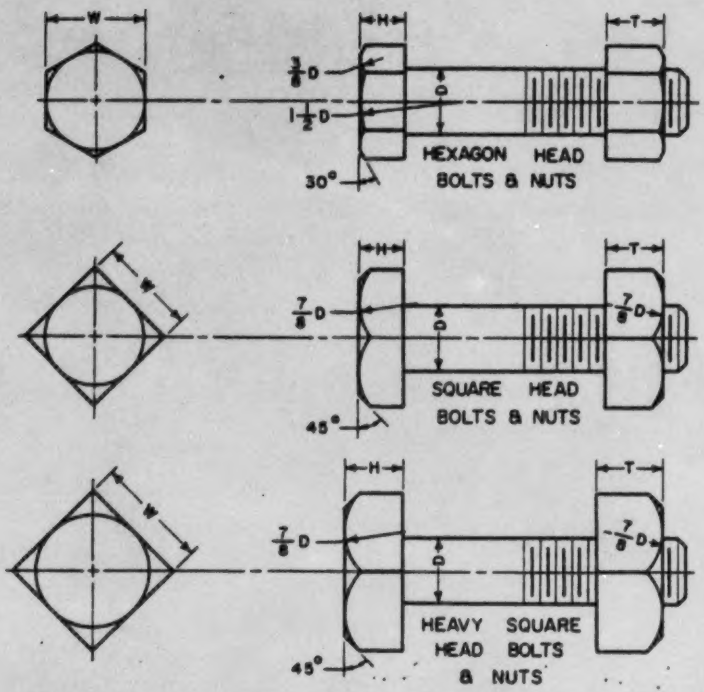
Form. The head on unfinished, regular- and heavy-series bolts and nuts may be square or hexagonal. On all others the head form is hexagonal. The corners are chamfered to form a flat circular top having a diameter equal to the distance across flats.

Chamfer. The angle of chamfer with the flat top of bolts and nuts is drawn at 30° (45° for the heavy series).

Head height. This is the overall height of the bolthead and for semifinished or finished bolts includes the washer-faced bearing surface (see **washer face,** above).

Thickness of nuts. This is the overall thickness of the nut and for semifinished or finished nuts includes the washer-faced bearing surface (see **washer face,** above).

b. Approximate procedure for drawing bolts and nuts. This method is acceptable whenever drawing to exact sizes is not necessary to prescribe clearances. The only information required is: (1) diameter, (2) length, and (3) the type of head or nut. The width (W), height (H), or thickness (T) is then approximated in proportion to the diameter


W
H
T
3/8 D
1 1/2 D
D
30°
HEXAGON HEAD BOLTS & NUTS
W
H
T
7/8 D
D
7/8 D
45°
SQUARE HEAD BOLTS & NUTS
W
H
T
7/8 D
D
7/8 D
45°
HEAVY SQUARE HEAD BOLTS & NUTS

Semi-finished Regular	Unfinished Regular	Unfinished Heavy
$W = 1\frac{1}{2} D$ $H = \frac{3}{4} D$ $T = \frac{7}{8} D$	$W = 1\frac{1}{2} D$ $H = \frac{2}{3} D$ $T = \frac{7}{8} D$	$W = 1\frac{1}{2} D + \frac{1}{8}$ $H = \frac{W}{2}$ $T = D$

Figure 3-7. Bolt and nut formulas.

(D) of the bolt, thus saving considerable drafting time. Figure 3-7 shows the formulas used to determine the dimensions for W, H and T together with suggested radii for drawing arcs of boltheads and nuts. Figure 3-8 illustrates the procedure in drawing square and hexagonal bolts and nuts.

Step 1. Draw centerline and lines representing the diameter (D).

Step 2. On centerline, draw circle of radius ¾ D (diameter = 1½ D). For unfinished heavy series, diameter = 1½ D + ⅛ inch.

Step 3. With triangles, circumscribe hexagon (or square) about circle of step 2, representing form of bolthead or nut with distance across corners presented at right angles to centerline of step 1. This completes end view of bolthead or nut.

Step 4. From end view of step 3, project bolthead and nut to profile view.

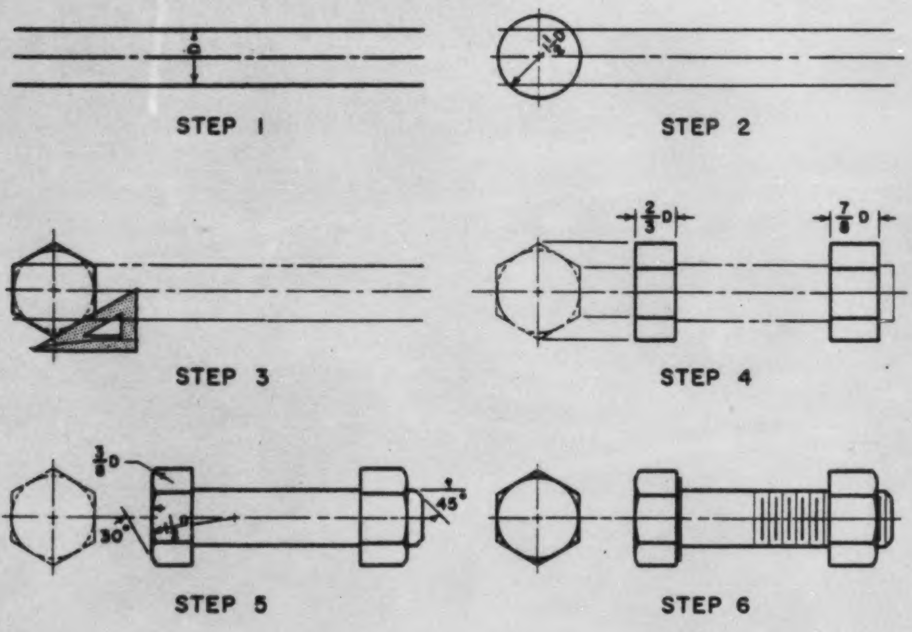


Figure 3-8. Steps in drawing bolts and nuts.

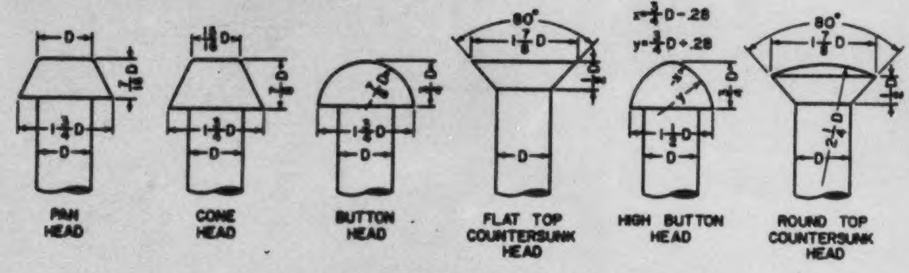
Step 5. Project arcs in bolthead and nut in accordance with radii as specified in figure 3-7.

Step 6. Draw washer face on nut or bolthead, if required, and chamfers on nut, bolthead and end of thread. Draw threads on bolt (regular symbol) as shown in figure 3-4. See thread length, paragraph 3a above.

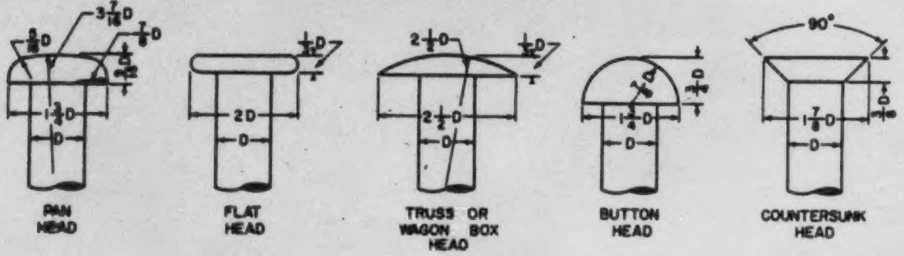
4. RIVETS

Riveting is a method of making a permanent joint between two metal parts.

a. Forms of rivet heads. All holes for rivets are punched or drilled in the fabricating shop, whether the rivets are driven in the field or in the shop. Large rivets are usually heated to make the metal softer and easier to work. The rivet has a cylindrical body and its head may be conical, spherical or flat. In assembly, the second head may be formed in the same shape. Clearance is always allowed between the rivet body and the prefabricated hole; the diameter of a rivet hole is usually made 1/16 inch larger than the rivet diameter. To provide for filling this clearance the rivet is extended (beyond the surface of the parts being joined) a length equal to ¾ of its diameter for a flat or countersunk head; 1.3 to 1.7 times the diameter for other type heads. Standard forms of rivet heads and the formulas for drawing them are shown in figure 3-9.


PAN HEAD
CONE HEAD
BUTTON HEAD
FLAT TOP COUNTERSUNK HEAD
HIGH BUTTON HEAD
ROUND TOP COUNTERSUNK HEAD
90°
90°
D

(a) LARGE RIVETS


PAN HEAD
FLAT HEAD
TRUSS OR WAGON BOX HEAD
BUTTON HEAD
COUNTERSUNK HEAD
2D
90°
D

(b) SMALL RIVETS

Figure 3-9. Forms of rivet heads.

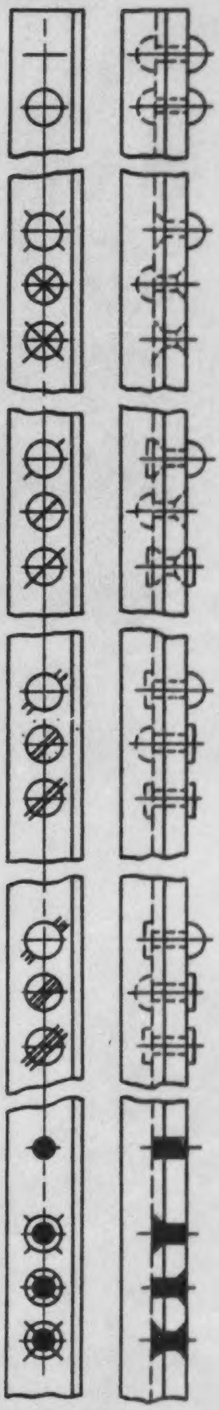
b. **Symbols.** Two different symbols are used to distinguish between shop and field rivets in detail drawings. Figure 3-10 shows the most common standard conventions. Notice that the rivet head diameter is used in drawing shop rivets, and the rivet body diameter is used for drawing field rivets. The blackened indication for field rivets indicates a hole in which rivets are placed later. Centerlines are used on detail drawings made to small scale, rivets being placed where the centerlines intersect. The centerlines represent the intersection of pitch and gage lines.

5. WELDING

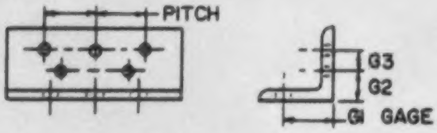
Welding is also a method of making a permanent joint between two metal parts, and its wide use has brought about a whole new language of symbols for use on drawings. The symbols and terms used are discussed in JAN-STD-19, Joint Army-Navy Standard for Welding Symbols. Figure 3-11 is a chart of various types of welding processes encountered most frequently.

a. **Welding symbol.** The basic welding symbol (fig 3-12) is simply a reference line forming an arrow, with one or more angle bends behind the arrowhead, which points to the location of the weld.

All information required to indicate the welding process to be used, the location and type of weld, the size, finish, and so on, is located in specified positions on or near the welding symbol.



Shop Rivets, Two Full Heads



Shop Rivets, Countersunk and Chipped, Near Side

Shop Rivets, Countersunk and Chipped, Far Side

Shop Rivets, Countersunk and Chipped, Both Sides

Shop Rivets, Countersunk but Not Chipped, Max. 1/8 in. High Near Side

Shop Rivets, Countersunk but Not Chipped, Max. 1/8 in. High Far Side

Shop Rivets, Countersunk but Not Chipped, Max. 1/8 in. High Both Sides

Shop Rivets, Flattened to ¼ in. High for ½ in. and 5/8 in. Rivets Near Side

Shop Rivets, Flattened to ¼ in. High for ½ in. and 5/8 in. Rivets Far Side

Shop Rivets, Flattened to ¼ in. High for ½ in. and 5/8 in. Rivets Both Sides

Shop Rivets, Flattened to 3/8 in. High for 3/4, 7/8, and 1 in. Rivets Near Side

Shop Rivets, Flattened to 3/8 in. High for 3/4, 7/8, and 1 in. Rivets Far Side

Shop Rivets, Flattened to 3/8 in. High for 3/4, 7/8, and 1 in. Rivets Both Sides

Field Rivets, Two Full Heads

Field Rivets, Countersunk and Chipped, Near Side

Field Rivets, Countersunk and Chipped Far Side

Field Rivets, Countersunk and Chipped Both Sides

Figure 3-10. Rivet conventions.

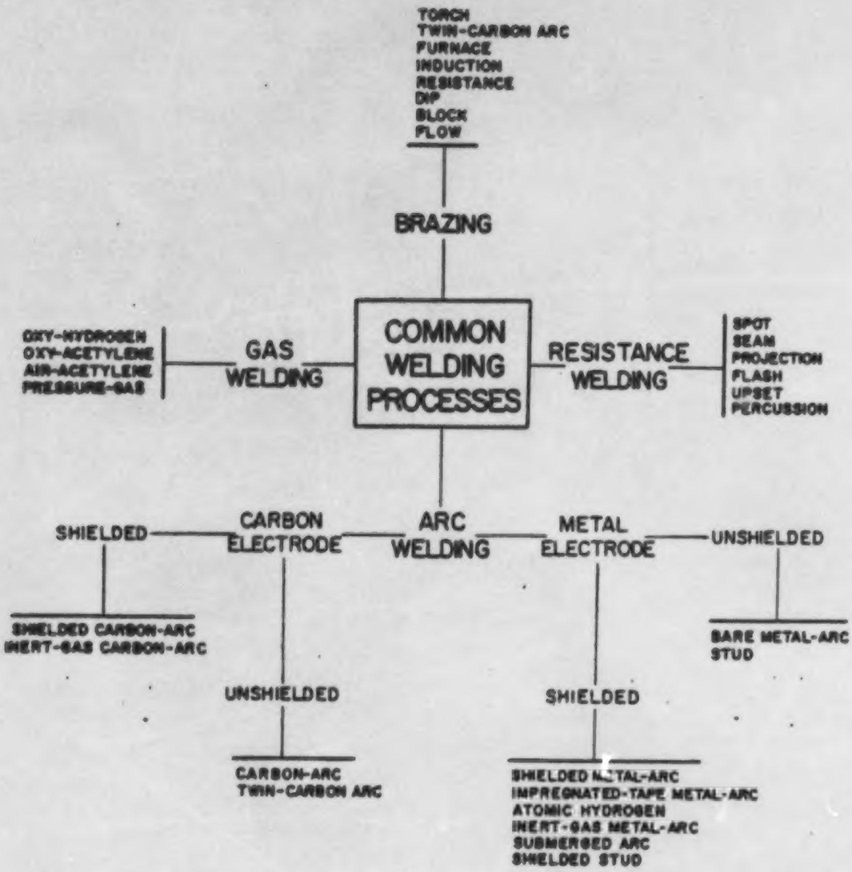

TORCH
TWIN-CARBON ARC
FURNACE
INDUCTION
RESISTANCE
DIP
BLOCK
FLOW
BRAZING
OXY-HYDROGEN
OXY-ACETYLENE
AIR-ACETYLENE
PRESSURE-GAS
GAS WELDING
COMMON WELDING PROCESSES
RESISTANCE WELDING
SPOT
SEAM
PROJECTION
FLASH
UPSET
PERCUSSION
SHIELDED
CARBON ELECTRODE
ARC WELDING
METAL ELECTRODE
UNSHIELDED
SHIELDED CARBON-ARC
INERT-GAS CARBON-ARC
BARE METAL-ARC
STUD
UNSHIELDED
SHIELDED
CARBON-ARC
TWIN-CARBON ARC
SHIELDED METAL-ARC
IMPREGNATED-TAPE METAL-ARC
ATOMIC HYDROGEN
INERT-GAS METAL-ARC
SUBMERGED ARC
SHIELDED STUD

Figure 3-11. Common welding processes.

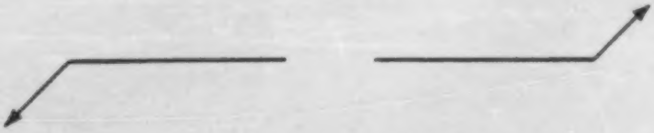
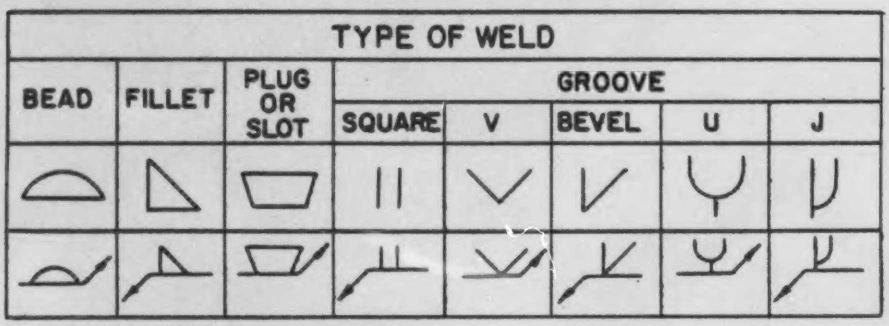


Figure 3-12. Basic welding symbol.

b. Arrow side and other side. To provide for identification, welds are classified as **arrow side** (previously called near side) or **other side** (previously termed far side). A weld on the near side of the joint, parallel to the drawing sheet and toward the observer, is called the arrow side. It is on the same side as the symbol, and the arrow points to its face.

The other side is on the opposite side of the joint, away from the observer, and its face is away from the arrow. (See fig 3-17.)

c. **Weld symbols.** Symbols used to indicate the type of weld are called basic weld symbols to differentiate them from the welding symbol, or arrow. Arc and gas weld symbols are shown in figure 3-13. Resistance weld symbols are shown in figure 3-14.


TYPE OF WELD
BEAD
FILLET
PLUG OR SLOT
GROOVE
SQUARE
V
BEVEL
U
J

NOTE — PERPENDICULAR LEG ALWAYS DRAWN LEFT HAND

Figure 3-13. Basic arc and gas weld symbols.

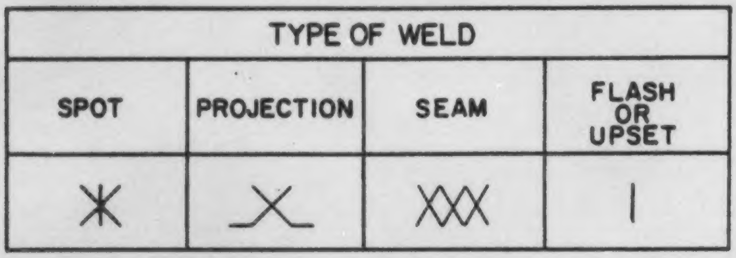

TYPE OF WELD
SPOT
PROJECTION
SEAM
FLASH OR UPSET

Figure 3-14. Basic resistance weld symbols.

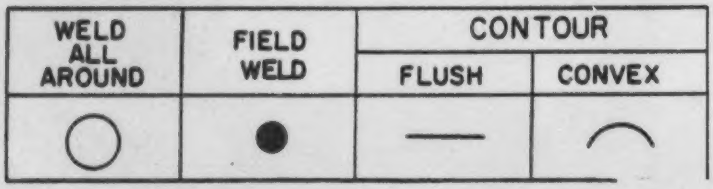

WELD ALL AROUND
FIELD WELD
CONTOUR
FLUSH
CONVEX

Figure 3-15. Supplementary symbols.

Other process or specification reference, when required, is noted in the tail of the welding symbol. (See fig 3-16.) Supplementary symbols which are used in connection with the weld symbols are shown in figure 3-15.

d. **Assembled welding symbol.** The weld symbols in their respective positions on the reference line and arrow, together with other data, form the completed welding symbol. The assembled welding symbol consists of the eight elements listed below, or as many of them as are necessary to show the requirements of a given weld. Finish symbols, as drawn, indicate the method (C = chipping, M = machining, G = grinding) of finishing and not degree of finish. The eight elements of an assembled welding symbol are:

Reference line
Arrowhead
Basic weld symbols
Dimensions and other data
Supplementary symbols
Finish symbols
Tail
Specification, process, or other reference

The standard locations of the elements on an assembled welding symbol are shown in figure 3-16.

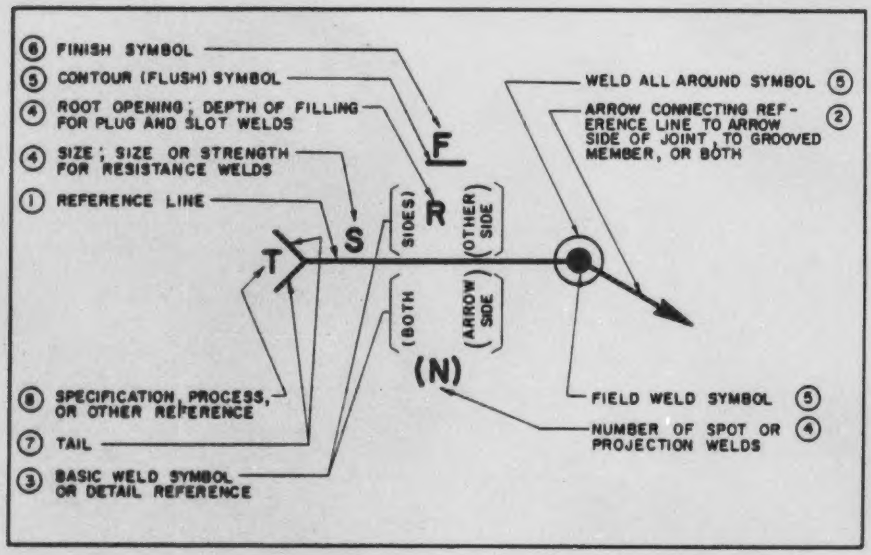

⑥ FINISH SYMBOL
⑤ CONTOUR (FLUSH) SYMBOL
④ ROOT OPENING; DEPTH OF FILLING FOR PLUG AND SLOT WELDS
④ SIZE; SIZE OR STRENGTH FOR RESISTANCE WELDS
① REFERENCE LINE
F
R
S
T
(SIDES)
(OTHER SIDE)
(BOTH
(ARROW SIDE)
(N)
WELD ALL AROUND SYMBOL ⑤
ARROW CONNECTING REFERENCE LINE TO ARROW SIDE OF JOINT, TO GROOVED MEMBER, OR BOTH ②
⑧ SPECIFICATION, PROCESS, OR OTHER REFERENCE
⑦ TAIL
③ BASIC WELD SYMBOL OR DETAIL REFERENCE
FIELD WELD SYMBOL ⑤
NUMBER OF SPOT OR PROJECTION WELDS ④

Figure 3-16. Standard location of elements on the welding symbol.

Figure 3-17 shows the types of welded joints and some applications of the welding symbol.

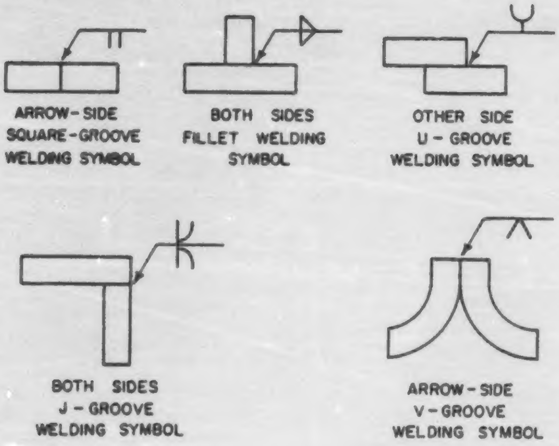

ARROW-SIDE
SQUARE-GROOVE
WELDING SYMBOL
BOTH SIDES
FILLET WELDING
SYMBOL
OTHER SIDE
U-GROOVE
WELDING SYMBOL
BOTH SIDES
J-GROOVE
WELDING SYMBOL
ARROW-SIDE
V-GROOVE
WELDING SYMBOL

Figure 3-17. Application of the welding symbol.

6. PRACTICE WORK

This practice work affords another opportunity for you to check your progress. Check your answers with the solutions at the back of the booklet. Restudy the attached memorandum where necessary. DO NOT send in your answers to these exercises.

First requirement. Exercise 1 is designed to give you practice in drawing screw threads, bolts and nuts, rivets and welding symbols.

1. Complete **plate** G according to the instructions thereon. Draw all construction lines with a 6H pencil, crest of threads with a 4H pencil, and all finish lines with a 2H pencil. DO NOT submit this practice sheet.

Second requirement. The following four exercises are true or false. If you believe a statement is true check "T", if false or only partly true check "F".

2. Left-hand threads advance when turned clockwise. T F
3. The depth of a thread is equal to the difference between the major and minor diameters. T F
4. Formulas for drawing bolts and nuts are generally given in terms of the length (L) of the bolt. T F
5. The standard convention for showing shop rivets on a drawing is based on the rivet body diameter. T F

Third requirement. Multiple-choice exercises 6 through 10 should enable you to test your understanding of the conventional methods used for showing various types of fasteners on drawings.

6. The depth of a thread may be determined by:
   - a. measurements made parallel with the axis
   - b. dividing its pitch by the lead
   - c. taking ½ the difference of its major and minor diameters
   - d. counting the number of threads

7. On an engineering drawing screw threads are illustrated by:
   - a. orthographic or conventional system
   - b. semiconventional or symbolic representation
   - c. isometric or freehand sketching
   - d. photographic or perspective drawing

8. The head on a semifinished bolt is:
   - a. either square or hexagonal
   - b. always square
   - c. one-half the diameter
   - d. always hexagonal

9. To provide for filling the clearance allowed between the rivet body and the hole into which it is to be inserted, a rivet which is to have a countersunk head is extended a length equal to:
   - a. 1.3 to 1.7 times its diameter
   - b. twice the size of the head to be formed
   - c. three-fourths of its diameter
   - d. the diameter of the rivet body

10. The perpendicular leg of a weld symbol is always drawn to:
   - a. right hand
   - b. near side
   - c. left hand
   - d. far side

EXERCISES

First requirement. Exercises 1 and 2 will enable you to demonstrate your ability to draw screw threads of various types. Also to demonstrate just how well you can draw a bolt and nut. Follow the instructions carefully; your work will be graded on neatness, completeness, and accuracy.

1.

The upper half of plate H shows a series of one-inch blocks which are to be filled in with various types of screw threads. The requirement is to draw threads as indicated by the title of each block and to show only ONE dotted line for a hidden thread in each block.

The engineer's scales marked 50, 60 and 40 are most convenient for marking the pitch distances for 5, 6 and 8 threads per inch.

2.

The lower half of **plate H** shows two pieces T and V to be bolted together. The requirement is to draw the bolthead and nut according to the given information; scale, 12" = 1'-0". Use the regular symbol for representation of the threads. DO NOT show dimensions.

Refer to figures 3-7 and 3-8 in drawing bolthead and nut.

Second requirement. Solve multiple-choice exercises 3 through 12 to show that you understand the basic forms of permanent and removeable fasteners and the conventional method of their presentation. In solving these exercises, test your answers against your plates G and H. The accuracy of your drawing may lead to the answer to an exercise; or the correct answer to an exercise will help you check the accuracy of your drawing.

3.

With the centerline already given in **block A, plate G,** the next procedure in making the semiconventional representation of the required screw thread was to:

a. mark off the pitch distances on minor diameter line
b. select the right-hand thread guide
c. draw the lines necessary to locate the major and minor diameters
d. draw lines to form the crests and roots of the threads

4.

Which of the following are NOT shown by regular or simplified thread symbols?

a. V profile
b. length
c. threaded portion
d. major diameter

5.

The question mark (?) in the specification note (**block A, plate G**) refers to the number of threads per inch and from table I is found to be:

a. 5
b. 6
c. 7
d. 8

6.

The diameter of the washer face on the nut (**block C, plate G**) should equal the distance across flats, which to be drawn correctly is:

a. ⅔ D
b. ⅞ D
c. 1¼ D
d. 1½ D

7.

The 1" bolt drawn on **plate H** should be threaded for a distance of 1½ times D plus ⅛ inch, or:

a. 1⅛"
b. 1⅝"
c. 2"
d. 2½"

8.

The thickness (T) for the hexagonal nut on plate H, is found by the formula (figure 3-7), if drawn correctly is:

a. ⅝"
b. ¾"
c. ⅞"
d. 1"

9.

On the thread end, bolts are chamfered at an angle of:

a. 30°
b. 45°
c. 60°
d. 90°

10.

The diameter of the head for the rivet specified in block D, plate G, was determined to be:

a. 1/4
b. 5/16
c. 3/8
d. 7/16

11.

To distinguish them from shop rivets, field rivets are indicated by:

a. the letter F
b. a note
c. a black dot
d. a cross

12.

Which of the weld symbols is similar to a rivet symbol?

a. field weld
b. bead
c. slot
d. all around

LESSON 4

DETAIL AND ASSEMBLY PRACTICES

CREDIT HOURS __________3

TEXT ASSIGNMENT ______Attached memorandum.

MATERIALS REQUIRED ____Drafting kit and plates I, J.

LESSON OBJECTIVE ______To teach you the relationships between detail and assembly drawings and the practices for making them.

SUGGESTIONS __________Refer to the suggestions made for lesson 1.

ATTACHED MEMORANDUM

1. DETAIL AND ASSEMBLY DRAWING SYNONYMOUS WITH WORKING DRAWINGS

Detail and assembly drawings have been identified as components of a set of working drawings (Engineering Drawing I). Each detail drawing and assembly drawing, separately or in combination, constitutes a working drawing. The same general procedure for making working drawings should be followed in making detail and assembly drawings. These include sheet layout, selection of views, selection of scales, application of centerlines, and dimensioning. Remember the detail drawing gives all necessary shop information for the production of individual items, and an assembly drawing shows the location of each item in relation to one another. (See figure 4-1.)

2. DETAIL DRAWING

In addition to being familiar with the general procedures for making working drawings the draftsman must understand the requirements governing detail practices. These vary according to their intended use. In general, the draftsman is concerned with two main categories: mechanical and construction drawing. The latter is subdivided into structural practices and architectural practices which are covered more completely in lesson 7. Only a few significant elements, pertinent to the treatment of details in general, are dealt with in this lesson.

3. MECHANICAL PRACTICE

In machine drawing, two systems are employed. Both follow the practice of drawing the details of each piece individually on a separate sheet; when the end item is small and consists of only a few parts, the

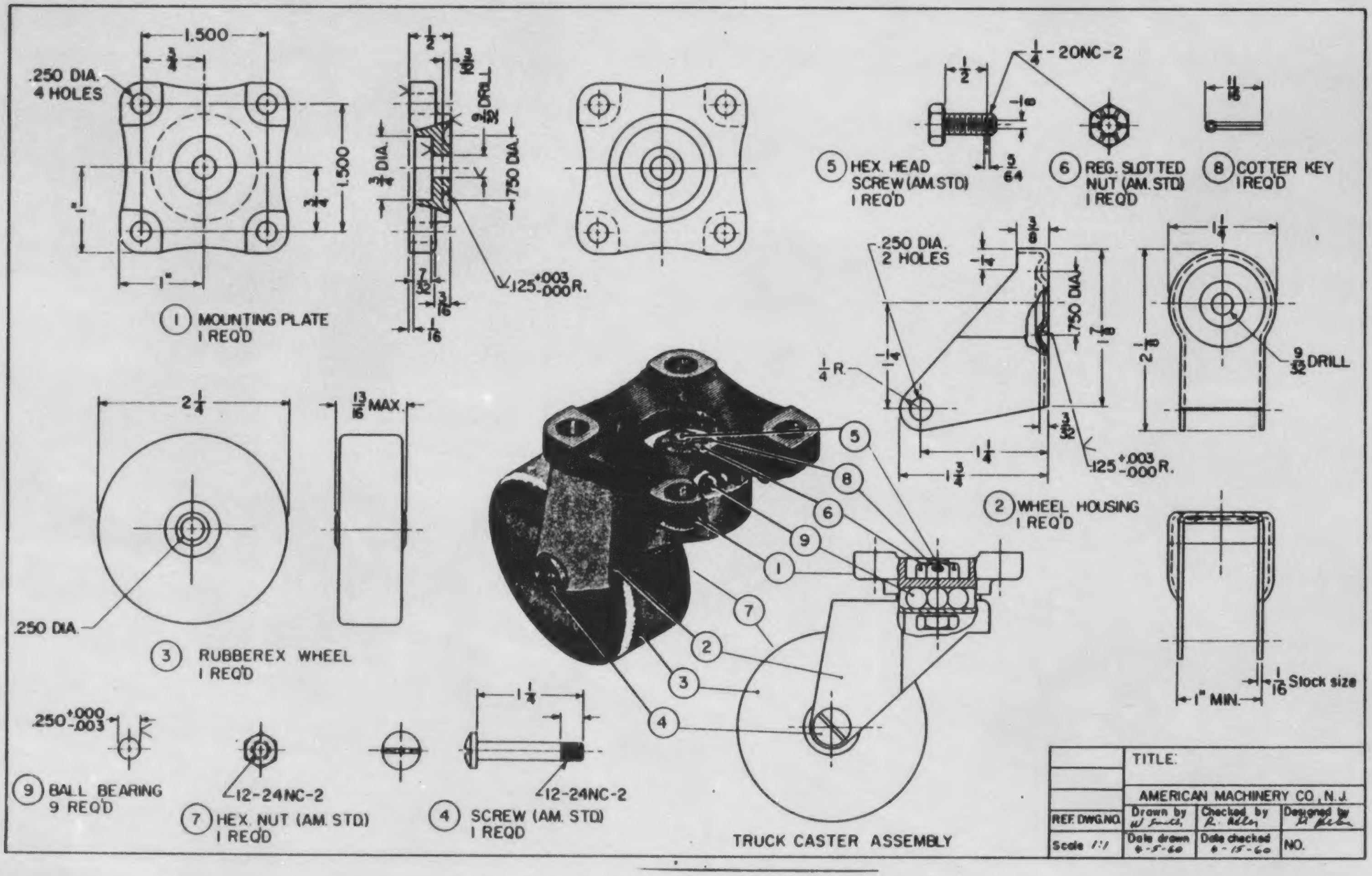

1.500
3/4
.250 DIA.
4 HOLES
1.500
3/4
1"
1"
① MOUNTING PLATE
1 REQ'D
1/2
1/16
9/32 DRILL
3/4 DIA.
.750 DIA.
7/32
3/16
1/16
.125 +.003 -.000 R.
1/2
1/4 - 20NC-2
1/8
5/64
11/16
⑤ HEX. HEAD SCREW (AM. STD.)
1 REQ'D
⑥ REG. SLOTTED NUT (AM. STD.)
1 REQ'D
⑧ COTTER KEY
1 REQ'D
3/8
.250 DIA.
2 HOLES
1/4
.750 DIA.
1 7/8
1 1/4
1/4 R.
3/32
1 1/4
1 3/4
.125 +.003 -.000 R.
② WHEEL HOUSING
1 REQ'D
1 1/4
2 1/8
9/32 DRILL
2 1/4
13/16 MAX.
.250 DIA.
③ RUBBEREX WHEEL
1 REQ'D
1" MIN.
1/16 Stock size
.250 +.000 -.003
⑨ BALL BEARING
9 REQ'D
12-24NC-2
⑦ HEX. NUT (AM. STD.)
1 REQ'D
1 1/4
12-24NC-2
④ SCREW (AM. STD.)
1 REQD
5
8
6
9
1
7
2
3
4
TRUCK CASTER ASSEMBLY
TITLE:
AMERICAN MACHINERY CO., N.J.
REF. DWG. NO.
Drawn by W. Smith
Checked by R. Adler
Designed by
Scale 1:1
Date drawn 6-5-60
Date checked 6-15-60
NO.

Figure 4-1. Relation of details versus assembly.

details may be shown on the same sheet with the assembly drawing, as in figure 4-1.

a. Multiple-drawing system. Some manufacturers use the multiple-drawing system, in which different drawings are made for the pattern shop, the foundry, and machine shop. In this case, each drawing presents only that information required by the shop for which the drawing is intended.

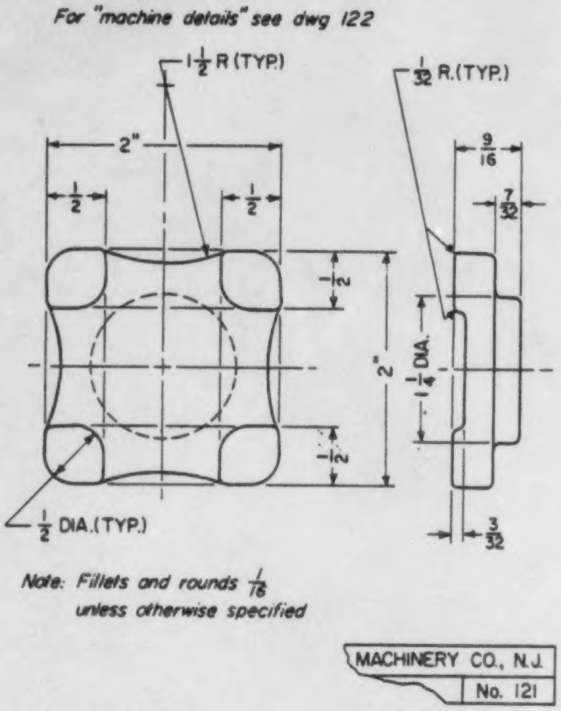

For "machine details" see dwg 122
1 1/2 R (TYP.)
1/32 R. (TYP.)
2"
1/2
1/2
9/16
7/32
1/2
2"
1 1/4 DIA.
1/2
1/2 DIA. (TYP.)
3/32
Note: Fillets and rounds 1/16 unless otherwise specified
MACHINERY CO., N.J.
No. 121

Figure 4-2. Detail drawing for the foundry.

Figures 4-2 and 4-3 are multiple drawings, figure 4-2 is for the foundry, and figure 4-3 is for the machine shop. Notice how each drawing gives only that information required by the using shop; on the other hand, notice that both drawings are cross-referenced to each other.

b. Single-drawing system. The practice most commonly followed employs the single-drawing system, in which all information necessary for the completion of the finished piece is made to be used by all shops involved in its production.

Figure 4-4 is a single drawing to be used by both the foundry and the machine shop. Notice how the information required by each shop is given separately so that one set of dimensions and

For "casting details" see dwg 121

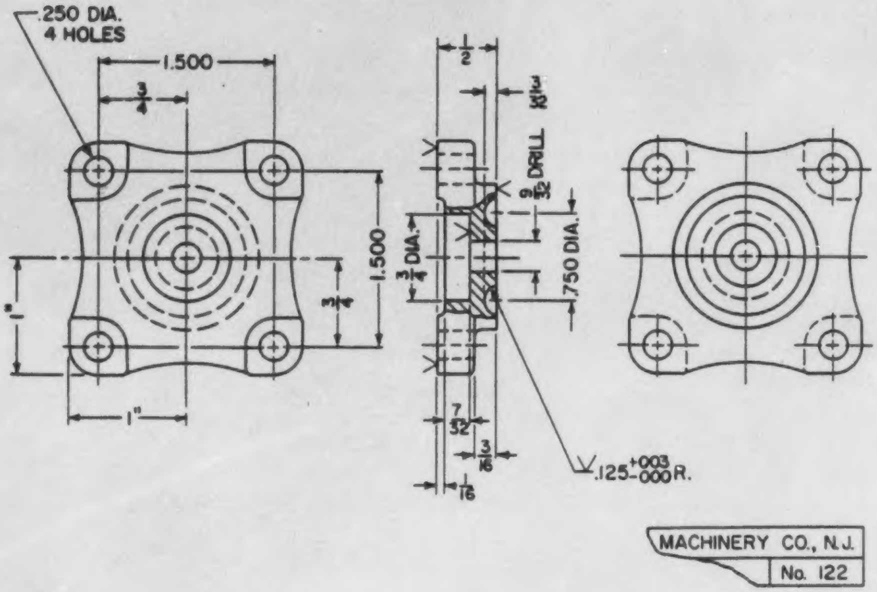

.250 DIA.
4 HOLES
1.500
3/4
1.500
3/4
1"
1"
1/2
3/32
9/32 DRILL
3/4 DIA.
.750 DIA.
7/32
3/16
1/16
.125 +.003 −.000 R.
MACHINERY CO., N.J.
No. 122

Figure 4-3. Detail drawing for the machine shop.

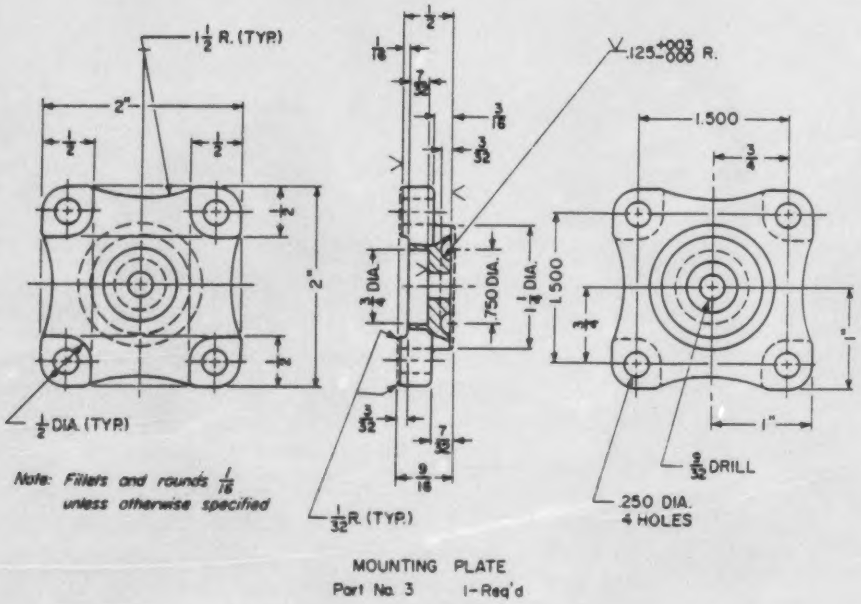

1 1/2 R. (TYP.)
2"
1/2
1/2
1/2
2"
1/2
1/2 DIA. (TYP.)
Note: Fillets and rounds 1/16 unless otherwise specified
1/2
1/16
7/32
3/16
3/32
.125 +.003 −.000 R.
3/4 DIA.
.750 DIA.
1 1/4 DIA.
3/32
7/32
9/16
1/32 R. (TYP.)
1.500
3/4
1.500
3/4
1"
1"
9/32 DRILL
.250 DIA.
4 HOLES
MOUNTING PLATE
Part No. 3 1-Req'd

Figure 4-4. Single drawing for use by all shops.

data is not dependent on the other; also note that the need for cross-reference is eliminated.

c. **Finish marks.** In dimensioning a machine detail, the draftsman should mark all surfaces of a casting or forging that are to be machined. Such marking not only indicates the machining operation but also suggests to the pattern maker where to provide extra metal on the rough casting or forging to allow for machine finishing. Figure 4-5 shows the two types of finish marks in use and illustrates the method of their construction and placement. The standard mark recommended by the American Standards Association (ASA) is a 60° V with its point touching the surface to be machined while the wings are in the air (away from the object). Figures 4-3 and 4-4 show the application of the standard mark. Finish marks should be placed on all views in which the surface to be finished appears as a line, even if the line is a dotted line. As previously stated (Engineering Drawing I), if the part is to be finished on all surfaces, it is treated by the general note "Finish All Over".

d. **Other notes.** Rounds and fillets occurring a number of times on a drawing are only identified once for each variation in size. The note **"TYP"** (abbreviation for typical) is then added to indicate that the dimension is typical for all other similar rounds and fillets (fig 4-2). This same note may be applied to similar dimensions on a drawing.

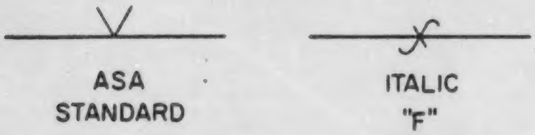


Figure 4-5. Finish marks.

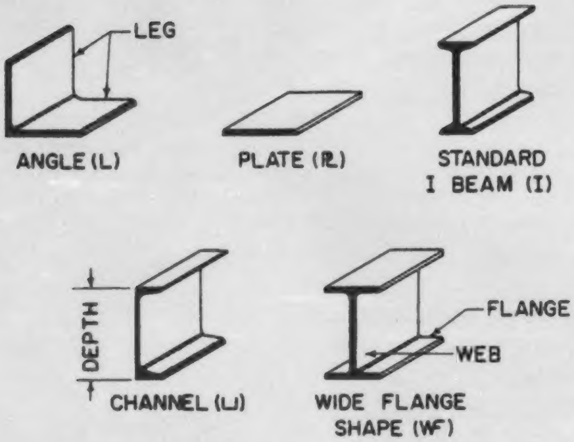


Figure 4-6. Rolled-steel shapes.

4. STRUCTURAL DETAILS

In structural drawing, few general rules can be given for presenting details because of the variety of materials worked with and the methods used in their fabrication. Typical details are discussed in relation to materials; only structural steel, reinforced concrete and wood are discussed in this subcourse.

5. STRUCTURAL STEEL DETAILS

a. Common shapes. Steel structures are composed of rolled-steel shapes used either singly or built up to form members. Figure 4-6 shows sections of the common shapes together with the symbols used to identify them in notes, dimensions, and bills of materials. Dimensions for detailing these and other less used shapes are described completely in the American Institute of Steel Construction (AISC) handbook or military standard specifications. Abbreviations and order of specifications for the shapes given in figure 4-6 are as follows:

Equal angles. L 2 x 2 x 3/16 x 8′-0″ (size of legs x thickness x length)

Unequal angles. L 5 x 3 x ⅜ x 6′-0″ (size of long leg x size of short leg x thickness x length)

Plates. Pl 12 x ¾ x 3′-6″ (width x thickness x length)

Channels. 6⊔ 10.5 x 9′-8″ (depth x weight/foot x length)

I beams. 10 I 35.0 x 12′-6″ (depth x weight/foot x length)

Wide flangle shapes. 16 WF 64 x 18′-3″ (nominal depth x weight/foot x length)

b. Actual size and weight versus nominal size classification. The process for rolling structural-steel shapes permits a wide range of actual sizes and weights within a single nominal size classification. Although a beginning construction draftsman may not be required to prepare steel detail drawings, he should be aware of the reasons for specifying members in the manner described above. Steel details cannot be prepared without a structural steel handbook that specifies the actual dimensions for the various weights. Example of such data are given in tables I, II and II.

TABLE I. *American Standard Channels.*
Dimensions for detailing

Depth of section	Weight per foot	Flange		Web
		Width	Mean thickness	Thickness
in	lb	in	in	in
6	13.0	2⅛	⅜	7/16
	10.5	2	⅜	5/16
	8.2	1⅞	⅜	3/16

TABLE II. *American Standard Beams.*

Dimensions for detailing

Depth of section	Weight per foot	Flange		Web
		Width	Mean thickness	Thickness
in	lb	in	in	in
10	35.0	5	½	⅝
	25.4	4⅝	½	5/16

TABLE III. *Wide Flange Shapes.*

Dimensions for detailing

Nominal size	Weight per foot	Depth	Flange		Web
			Width	Thickness	Thickness
in	lb	in	in	in	in
16 x 11½	96	16⅜	11½	⅞	9/16
	88	16⅛	11½	13/16	½
16 x 8½	78	16⅜	8⅝	⅞	9/16
	71	16⅛	8½	13/16	½
	64	16	8½	11/16	7/16
	58	15⅞	8½	⅝	7/16
16 x 7	50	16¼	7⅛	⅝	⅜
	45	16⅛	7	9/16	⅜
	40	16	7	½	5/16
	36	15⅞	7	7/16	5/16

c. **Shop drawings.** Steel structural members are prepared in special fabricating shops, and the drawings showing the required fabrication of parts and methods of assembly are called shop detail drawings or simply **shop drawings.** Figure 4-8 is a shop drawing of a structural steel member made from a single rolled shape. Figures 4-7, 4-9 and 4-10 are shop drawings of members built up of a combination of rolled shapes. The practices for detailing structural steel, as illustrated by these figures, include the following:

(1) **Working lines and working points.** Shop drawings are made about light **working lines** laid out first along the centerlines or rivet gage lines to form a skeleton of the assembled member. The intersections of these working lines are called **working points** from which all dimensions are given. This skeleton is usually the same as, or taken from,

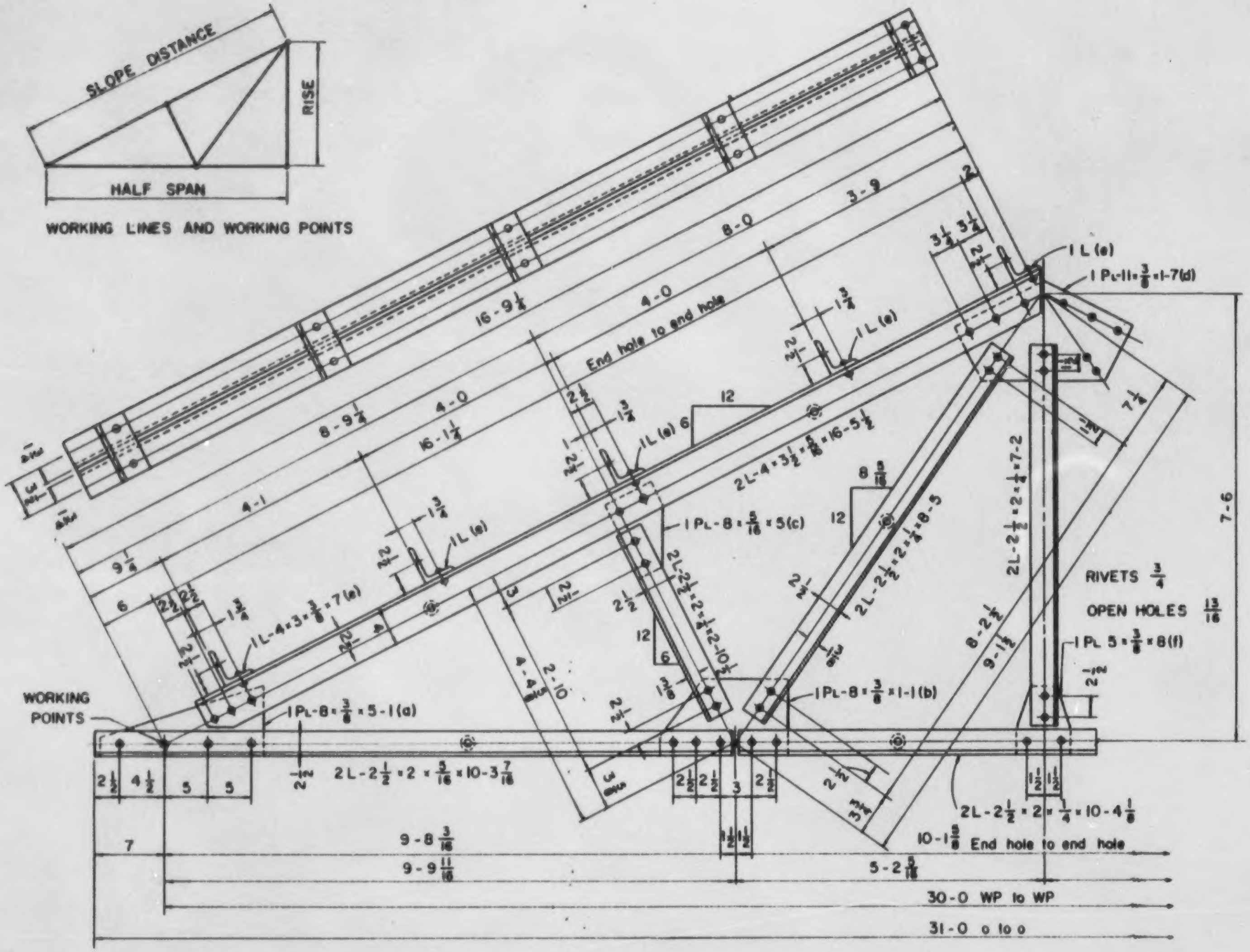

SLOPE DISTANCE
RISE
HALF SPAN
WORKING LINES AND WORKING POINTS
16-9 1/4
8-9 1/4
4-0
16-1 1/4
4-1
9 1/4
6
8-0
4-0
3-9
2
End hole to end hole
3 1/4 3 1/4
1 L (e)
1 PL-11 × 3/8 × 1-7(d)
12
6
1L (e)
1 L (e)
2L-4 × 3 1/2 × 5/16 × 16-5 1/2
1 PL-8 × 5/16 × 5(c)
2L-2 1/2 × 2 × 1/4 × 2-10 5/8
8 5/16
12
2L-2 1/2 × 2 × 1/4 × 8-5
2L-2 1/2 × 2 × 1/4 × 7-2
7 1/4
7-6
RIVETS 3/4
OPEN HOLES 13/16
1 PL 5 × 3/8 × 8(f)
8-2 1/2
9-1 1/2
1L-4 × 3 × 3/8 × 7(e)
4-4
2-10
1 PL-8 × 3/8 × 1-1(b)
WORKING POINTS
1 PL-8 × 3/8 × 5-1(a)
2L-2 1/2 × 2 × 5/16 × 10-3 7/16
2 1/2
4 1/2
5
5
2 1/2 2 1/2 3 2 1/2
1 1/2 1 1/2
2L-2 1/2 × 2 × 1/4 × 10-4 1/8
10-1 5/8 End hole to end hole
7
9-8 3/16
9-9 11/16
5-2 5/16
30-0 WP to WP
31-0 o to o

Figure 4-7. Shop drawing of typical steel truss.

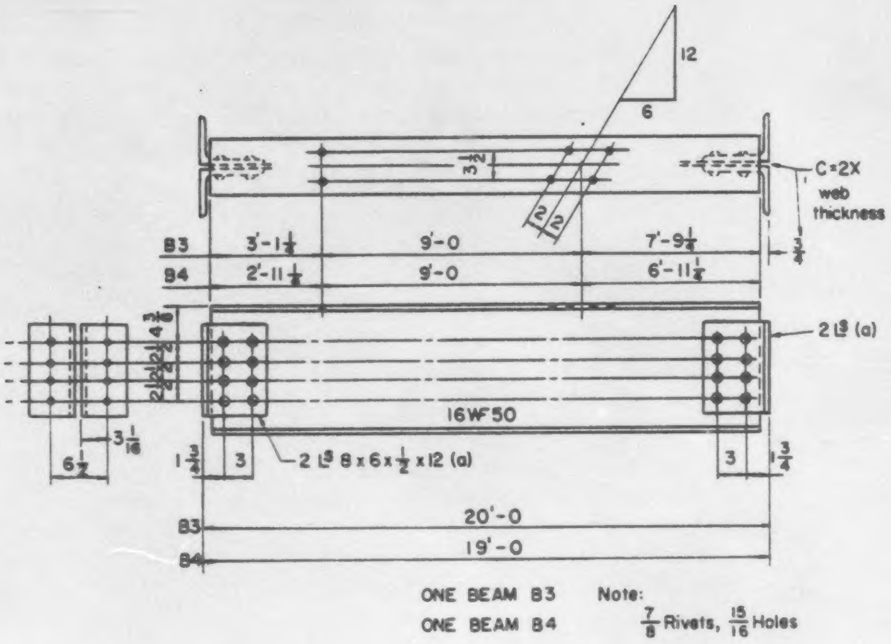

12
6
3 1/2
C=2X web thickness
2
2
B3
3'-1 1/4
9'-0
7'-9 1/4
3/4
B4
2'-11 1/4
9'-0
6'-11 1/4
2 L$ (a)
16WF50
3 1/16
6 1/2
1 3/4
3
2 L$ 8 x 6 x 1/2 x 12 (a)
3
1 3/4
B3
20'-0
B4
19'-0
ONE BEAM B3
ONE BEAM B4
Note:
7/8 Rivets, 15/16 Holes

Figure 4-8. Shop drawing of a beam.

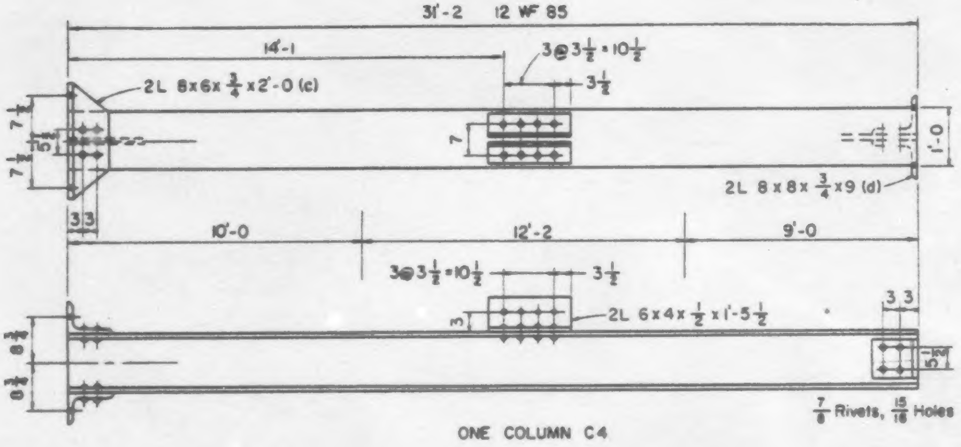

31'-2
12 WF 85
14'-1
3@3 1/2 = 10 1/2
3 1/2
2L 8x6x 3/4 x 2'-0 (c)
7 1/2
5 1/2
7 1/2
7
1'-0
2L 8 x 8 x 3/4 x 9 (d)
3 3
10'-0
12'-2
9'-0
3@3 1/2 = 10 1/2
3 1/2
3 3
3
2L 6 x 4 x 1/2 x 1'-5 1/2
8 1/2
8 1/2
5 1/2
7/8 Rivets, 15/16 Holes
ONE COLUMN C4

Figure 4-9. Shop drawing of a column.

the designer's stress diagram. Generally, the skeleton diagram is drawn to a small scale on the shop drawing (fig 4-7).

(2) **Relative position of parts.** Parts to be riveted or welded together in the shop are shown in the same relative position (vertical, horizontal or inclined, as in fig 4-7) which they will occupy in their assembled position in the structure, instead of being detailed individually, as is the practice for machine drawing.

> Note in figure 4-7 that due to the truss being symmetrical about each side of center, only half of the truss need be shown. In such cases, it is always the left end which is drawn.

(3) **Long vertical or inclined members.** Long vertical (columns) or inclined (braces) members are sometimes drawn in a horizontal position on the drawing. When thus drawn, a vertical member is drawn with the bottom at the left (fig 4-9), and an inclined member is drawn in the direction it would fall.

(4) **Scales** of shop drawings vary from ¼″ = 1′-0″ to 1″ = 1′-0″ depending on the size of the drawing sheet as compared with the size of the structural member. Usually two scales are used in the same view, one denoting length and the other showing the cross section at a larger scale than the length, as in figure 4-7. Often, it is expedient to disregard

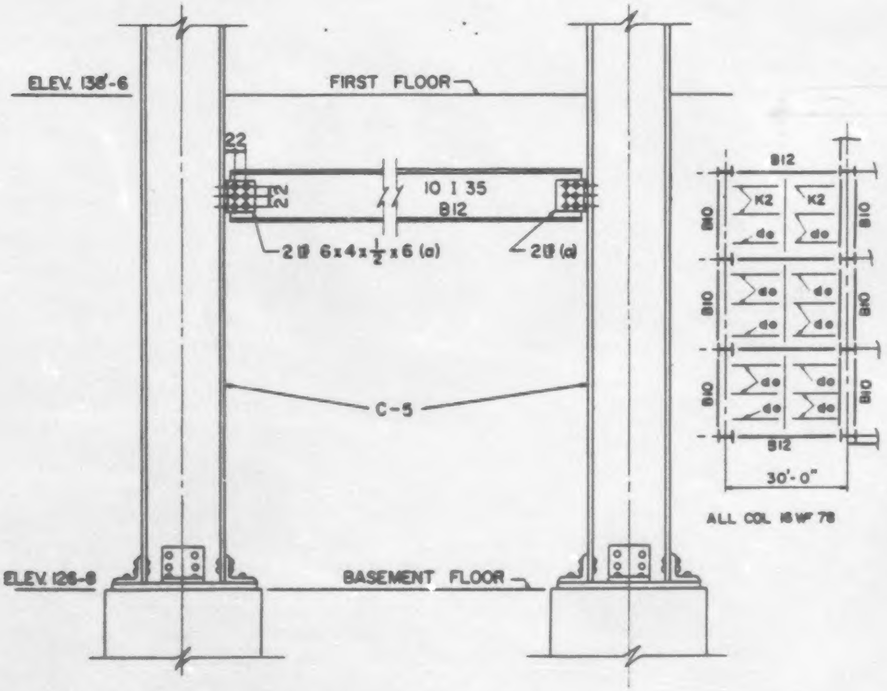

ELEV. 138'-6
FIRST FLOOR
22
2
2
10 I 35
B12
2 ⊾ 6x4x½x6 (a)
2 ⊾ (a)
C-5
ELEV. 128-6
BASEMENT FLOOR
B12
K2
K2
do
do
B10
B10
do
do
do
do
B10
B10
do
do
do
do
B10
B10
B12
30'-0"
ALL COL 16 WF 78

Figure 4-10. Typical steel frame construction.

scaled length and draw the member as if there were breaks in the length (although not shown on the drawing, as in fig 4-9) so that details of intermediate connections and rivet spacings at the ends can be drawn at the same scale as the cross section.

(5) **Dimensions** are always placed above the dimension line. Remember on construction drawings, the dimension lines are unbroken. Dimensions are given to centerlines and working lines, never to the outer edges of rolled shapes (except for length dimensions), and extension lines are drawn in accordance with routine drawing practice. When members differ in length only, they may be shown by a single drawing. When thus drawn, the different lengths are given separately and are identified by erection marks at the left end of each dimension line. Figure 4-8 shows two beams detailed on the same drawing.

(6) **Sizes of rolled shapes** are specified by abbreviated notes as described in paragraph 5a. The specification note may be given along with the length dimension (fig 4-8) or is placed near and parallel to the part as in figures 4-7 and 4-9. In some cases, it is advantageous to place the specification right on the front view of the shape (fig 4-10).

(7) **Slopes** of members and inclined centerlines, cuts, and so on, are indicated by their tangents. The value of the angle is given by constructing a small right triangle (not necessarily to scale) with its hypotenuse on or parallel to the skewed line. The long leg of the triangle is always labeled 12, meaning 12 inches. Figure 4-7 illustrates the manner in which the slope triangle is used.

(8) **Erection marks** facilitate the identification of members. Like index marks on a road map, they consist of capital letters (B for beam, C for column, T for truss, and so on) indicating the type of member and a number giving the specific member in an assembly or its location in the structure. They are indicated in subtitles of shop drawings (fig 4-8) and on erection diagrams as in figure 4-10.

(9) **Assembly marks** identify the use of the same shape in more than one place. The member is completely specified once and then given an assembly mark (lower-case letter, to avoid confusing it with the erection mark). It is not necessary to repeat the complete specification in identifying similar members. For example, see the specification "2 ∠s 8 x 6 x ½ x 12 (a)" in figure 4-8.

6. REINFORCED CONCRETE DETAILS

The drawing of concrete structures requires careful attention in representation and specification. Location of the reinforcing steel is shown in detail drawings of the various structural members. However, it is not possible to show the shapes and sizes of the reinforcing bars by the usual orthographic views, and a systematic method of marking is used in which bars are identified by symbols and reference numbers. Once assigned, the same reference number is used to identify the bar in any view in which it appears. Reinforcement size-and-shape details are provided in a separate reinforcement detail drawing which consists of a reinforcement schedule and diagrammatic bar-bending details.

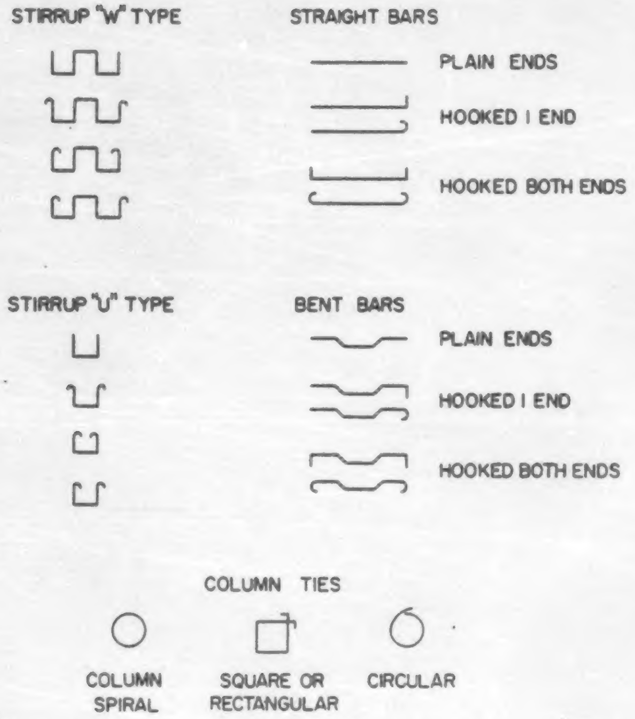

STIRRUP "W" TYPE
STRAIGHT BARS
PLAIN ENDS
HOOKED I END
HOOKED BOTH ENDS
STIRRUP "U" TYPE
BENT BARS
PLAIN ENDS
HOOKED I END
HOOKED BOTH ENDS
COLUMN TIES
COLUMN SPIRAL
SQUARE OR RECTANGULAR
CIRCULAR

Figure 4-11. Reinforcement symbols.

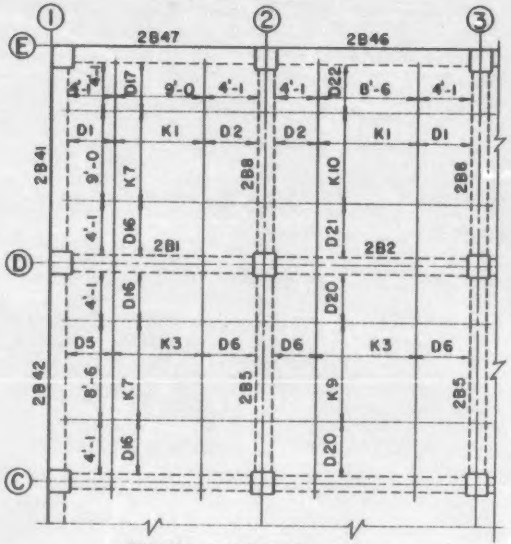
a. **Symbols.** The symbols used in preparing drawings of reinforced concrete structures include the material symbol for concrete in section and the symbols for reinforcing steel.

(1) **Concrete.** The symbol for concrete (fig 4-18) in section indicates coarse and fine aggregate and is drawn freehand. Fine aggregate is represented by fine dots and coarse aggregate by irregularly drawn triangles. Draw the large aggregate symbol first in random pattern and fill in sparsely with dots. Use 2H pencil (commercial No. 3) to prevent smearing.

(2) **Reinforcement.** Figure 4-11 presents the symbols for typical shapes of reinforcing steel. Figures 4-12, 4-13, and 4-14 demonstrate some applications of these symbols.

> Notice that in addition to their symbolic representation reinforcing bars parallel to the section are represented by heavy dashed lines; those perpendicular to the section are represented by heavy round or square dots, depending on the cross sectional shape of the bars.

b. **Reinforcing schedules.** Figure 4-12 shows a portion of a main floor plan and examples of reinforcing schedules for slabs, bar bends,



SECOND FLOOR FRAMING PLAN
ALL SLABS 5" THICK

SLAB SCHEDULE

	No. of Bonds	Bond Mark	Bar Spacing	BOTTOM BARS					TRUSS BARS					$\frac{7}{8}$ SLAB BOLSTERS		CONTINUOUS HIGH CHAIRS		
				No.	Length	Type	Sketch	Shipping Mark	No.	Length	Type	Sketch	Shipping Mark	No.	Length	No.	Length	Heigth
Lower Layer	2	D1	$8\frac{3}{4}$	2	19'-6	R500		5196	3	24'-6	R501		5246					
	2	D2	11	2	19'-6	R500		5196	2	24'-6	R501		5246					
	2	K1	$8\frac{3}{4}$	5	18'-6	R503		5186	8	29'-11"	R502		52911	4	16'-0	4	18'-3	$4\frac{1}{4}$
Upper Layer	3	D16	11	2	17'-3	R506		5173	2	24'-6	R511		5246					
	1	D17	$8\frac{3}{4}$	2	17'-9	R507		5179	3	24'-6	R511		5246					
	2	K7	$8\frac{3}{4}$	5	19'-6	R500		5196	8	24'-6	R511		5246			2	12'-0	$4\frac{3}{4}$

BENDING SCHEDULE

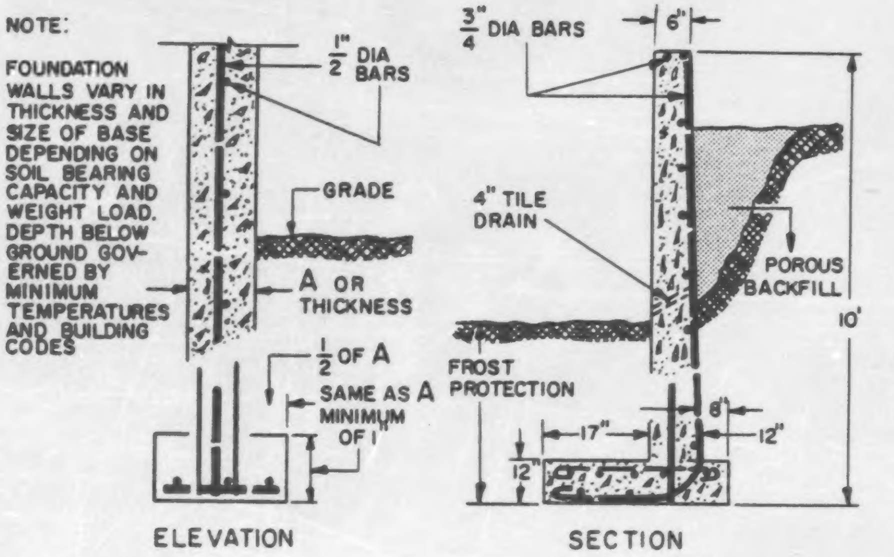
Type	Hk		Length	Type	Hk		S1		S2		H	J	Length
R500	6	19'-0	19'-6	R501	6	2'-9	$6\frac{1}{2}$	11'-6	$6\frac{1}{2}$	8'-8	$4\frac{1}{2}$		24'-6
R504	6	20'-3	20'-9	R502		8'-2	$6\frac{1}{2}$	9'-10	$6\frac{1}{2}$	8'-2	$4\frac{1}{2}$		23'-3

Note: All slab bars are $\frac{5}{8}$ ø.
All bending detail dimensions are out to out.

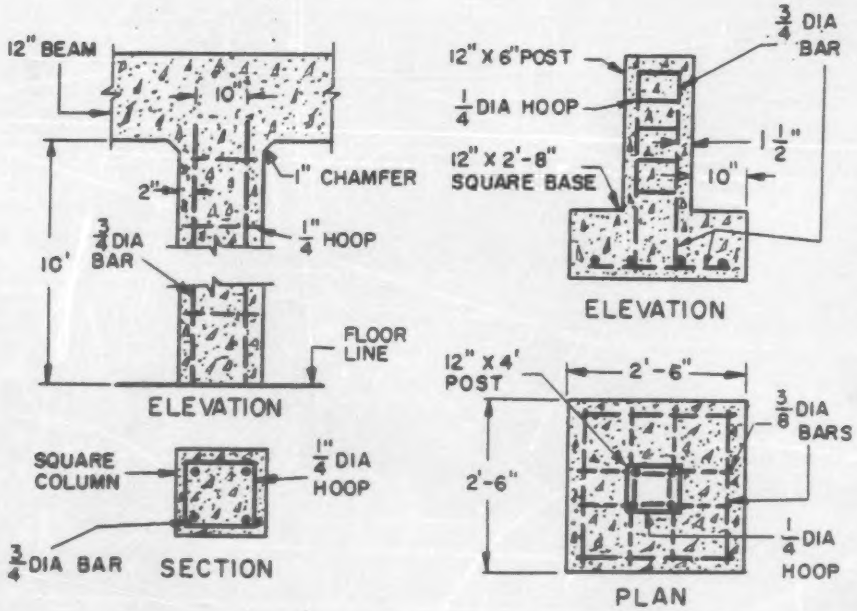
BEAM SCHEDULE

No. of Beams	Beam Mark	SIZE		STRAIGHT BARS					HOOK BARS							TRUSS BARS											LOCATION				STIRRUPS						
		Width	Depth	No.	Size	Length	Remarks	Shipping Mark	No.	Size	Length	Hook		Hook	Shipping Mark	No.	Size	Length	Hook		S1		S2		Hook	H		℄ of support	Remark	Shipping Mark	No.	Size	Length	BxC	Type	Spacing each end	2" Beam Bolsters
2	2B6	14	20	1	$\frac{7}{8}$	20'-6		7206	2	$\frac{7}{8}$	17'-10	9	18'-6		71710	2	1□	26'-7	1'-1	2'-4	1'-11	11'-0	1'-10	7'-7		1'-4				8267	14	$\frac{1}{2}$	5'-6	11x17	S1	2-3,3-6,5-9	4 at 1'-1
2	2B7	14	20	2	$\frac{7}{8}$	18'-6		7186								2	1ø	28'-1													14	$\frac{1}{2}$	5'-6	11x17	S1	do	4 at 1'-1

Figure 4-12. Typical reinforcing plan.

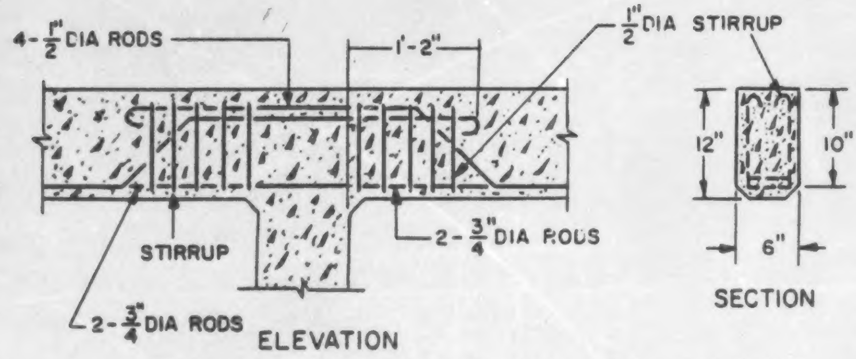

NOTE:
FOUNDATION WALLS VARY IN THICKNESS AND SIZE OF BASE DEPENDING ON SOIL BEARING CAPACITY AND WEIGHT LOAD. DEPTH BELOW GROUND GOVERNED BY MINIMUM TEMPERATURES AND BUILDING CODES
1/2" DIA BARS
GRADE
A OR THICKNESS
1/2 OF A
SAME AS A MINIMUM OF 1"
ELEVATION
3/4" DIA BARS
6"
4" TILE DRAIN
POROUS BACKFILL
10'
FROST PROTECTION
8"
17"
12"
12
SECTION

REINFORCED FOUNDATION WALL REINFORCED RETAINING WALL

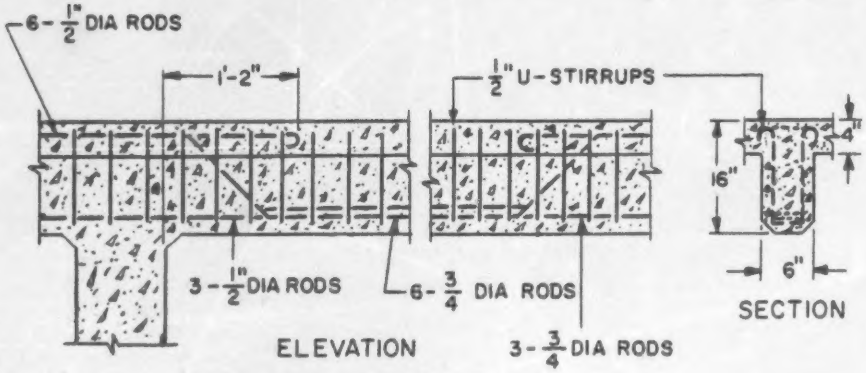

12" BEAM
10"
1" CHAMFER
2"
1/4" HOOP
3/4 DIA BAR
10'
FLOOR LINE
ELEVATION
SQUARE COLUMN
1/4" DIA HOOP
3/4 DIA BAR
SECTION
3/4 DIA BAR
12" X 6" POST
1/4 DIA HOOP
1 1/2"
12" X 2'-8" SQUARE BASE
10"
ELEVATION
12" X 4' POST
2'-6"
2'-6"
3/8 DIA BARS
1/4 DIA HOOP
PLAN

REINFORCED CONCRETE COLUMN REINFORCED CONCRETE PIER

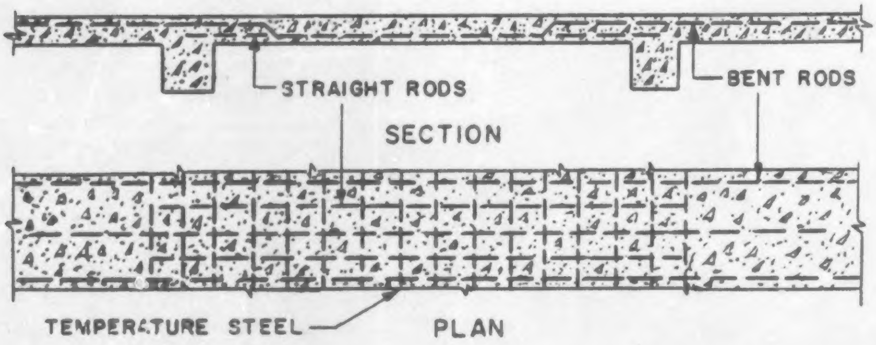
Figure 4-13. Common reinforced concrete structures.


4-$\frac{1}{2}$" DIA RODS
1'-2"
$\frac{1}{2}$" DIA STIRRUP
12"
10"
STIRRUP
2-$\frac{3}{4}$" DIA RODS
6"
SECTION
2-$\frac{3}{4}$" DIA RODS
ELEVATION

CONTINUOUS RECTANGULAR BEAM DETAIL


6-$\frac{1}{2}$" DIA RODS
1'-2"
$\frac{1}{2}$" U-STIRRUPS
4"
16"
3-$\frac{1}{2}$" DIA RODS
6-$\frac{3}{4}$ DIA RODS
6"
SECTION
ELEVATION
3-$\frac{3}{4}$ DIA RODS

CONTINUOUS T-BEAM DETAIL


STRAIGHT RODS
BENT RODS
SECTION
TEMPERATURE STEEL
PLAN

ONE-WAY REINFORCED CONCRETE SLAB FLOOR

Figure 4-14. Reinforcement details for beam and slab floors.

and beams as located on the plan. The No. column lists the quantity requirement; size refers to the bar diameter; length to the stretchout length; type to the shape of bar; and bending details to the outside lengths of the straight and curved segments. The shipping mark gives dimensions in code, the first number giving bar diameter in multiples of 1/8 inch and the other 3 or 4 numbers giving overall bar length in feet and inches. Mark 4073 means ½" dia @ 7'-3" long; mark 31810 means ⅜" dia @ 18'-10" long.

c. Bar-bending details. Bar-bending details resemble the diagrammatic shapes shown in figure 4-11. Note the manner in which bar bending details are indicated in reinforcing schedules (fig 4-12).

d. Section details. Figures 4-13 and 4-14 illustrate the manner in which basic information is given in typical reinforcement section details.

7. WOOD CONSTRUCTION DETAILS

Wood is a basic, almost universal, construction material and is used widely by the Army, particularly in theater of operations (TO) building. To prepare detail drawings, notes, schedules, and bills of material for wooden structures it is important that the construction draftsman has a thorough knowledge of its application. This section is concerned only with the practices for detailing framing of light structures such as one- or two-story buildings used as barracks, small shops, and so on. Practices for detailing doors, windows, stairs, and other finished trim, is covered under architectural practices (par 8, below).

a. Classification and grade. The kind and grade of wood to be used is noted on the drawing, listed in bills of material, or specifications.

(1) Wood is divided into two classes: hardwoods, which have broad leaves; and softwoods which have leaves like needles or scales.

Hardwoods. Some familiar native species of the hardwood or decidious class are ash, beech, birch, hickory, maple, and oak. Lumber cut from hardwoods is not generally used for the construction of structural framing, but is used principally for flooring, special interior paneling, trim and doors.

Softwoods. Most native species of softwoods bear cones and are called coniferous woods. Some familiar softwoods are cedar, fir, pine, spruce, and redwood. These woods are easily worked and make suitable material for structural framing. Of the various softwoods, southern yellow pine and Douglas fir are the varieties used most frequently for construction.

Southern yellow pine. All southern yellow pine used for structural purposes is classified as longleaf or shortleaf. When described in a bill of material or specifications, longleaf yellow pine is abbreviated as LLYP, and shortleaf yellow pine is abbreviated as SLYP.

Douglas fir. Douglas fir in the form of lumber and timber is one of the most desirable woods for structural purpose. It also has extensive use as poles, piling, or ties, and large quantities are cut into veneer for plywood and other purposes.

(2) Grading. Softwoods and hardwoods are graded by different standards. Only softwood grading is considered here because as explained previously, hardwoods are rarely used for structural purposes and the construction draftsman is seldom required to describe hardwoods in the notes or bill of material.

Grading criteria. In most cases, the grade of lumber is based on the number, character, and location of features such as knots, pitch pockets, and so on, which are commonly called defects and defined as any irregularity occurring in or on wood that may lower its strength, durability, or utility values. The best grades are practically free of these features; others, comprising the greater bulk of lumber, contain fairly numerous knots and other natural growth characteristics.

Select lumber is the general classification for lumber of good appearance and finishing qualities. Grades A and B are suitable for natural finishes; grades C and D are suitable for paint finishes.

Common lumber is the general classification for lumber containing the defects and blemishes described above. The grades are numbers 1 through 5. Nos. 1 and 2 are for use without waste in framing and sheathing; No. 3 can be used for temporary construction. Nos. 4 and 5 are NOT generally used in construction because they are of poor quality and are subject to much waste.

b. Surfacing and worked lumber. Lumber is further classified according to the manner in which it is milled.

(1) Surfacing. Lumber may be rough or dressed, depending on amount of planing done in the mill.

Rough lumber is as it emerges from the saw, or unplaned; when indicating rough lumber, the abbreviation is RGH.

Dressed or surfaced lumber is the rough lumber after it has been run through a planer. It may have any combination of edges and sides dressed, such as: (S1S) surfaced on 1 side; (S2S) surfaced on 2 sides; S1S1E surfaced on 1 side and 1 edge; and (S4S) surfaced on 4 sides.

(2) Worked lumber. Worked lumber is milled with a matcher, sticker, or molder; it can be matched, shiplapped, or patterned.

Matched lumber is cut so that it interlocks. A common type is tongue and groove (T & G), in which a groove is cut in one edge and a mating bead, or projection, is cut in the other edge. This type lumber is used largely in flooring and siding.

Shiplapped lumber is cut with a square step on either edge, the projection on one edge at the bottom and at the top on the other edge; in this way, adjacent boards overlap each other so as to form a joint. Shiplap is used largely for siding.

Patterned lumber is cut in many designs and is used for door and window trimming.

c. Actual and nominal sizes of lumber. Sizes of lumber are specified by nominal dimensions which differ from the actual dimensions of the milled pieces. When lumber is run through a saw and planer its nominal size remains the same but its actual size is reduced by the amount of surfacing it undergoes. Approximately ¼ inch is planed off each side in surfacing. Lumber is also divided into groups according to size, namely: strips — pieces less than 2 inches thick and under 8 inches wide; boards — less than 2 inches thick and more than 8 inches wide; dimensioned lumber — 2 to 6 inches thick and of any width; and timber — 6 or more inches in the least dimension. Dimensions of some common sizes are given in table IV.

TABLE IV. *Standard Sizes of Lumber (inches).*

STRIPS

Nominal size	1 x 2	1 x 3	1 x 4	1 x 6
Dressed size	25/32 x 1⅝	25/32 x 2⅝	25/32 x 3⅝	25/32 x 5⅝

BOARDS

Nominal size	1 x 4	1 x 6	1 x 8	1 x 10	1 x 12
Actual size, common			25/32 x 7½	25/32 x 9½	25/32 x 11½
Actual size, *shiplap	25/32 x 3⅛	25/32 x 5⅛	25/32 x 7⅛	25/32 x 9⅛	25/32 x 11⅛
Actual size, *T & G	25/32 x 3¼	25/32 x 5¼	25/32 x 7¼	25/32 x 9¼	25/32 x 11¼

* Width of face.

DIMENSIONED LUMBER

Nominal size	2 x 4	2 x 6	2 x 8	2 x 10
Actual size	1⅝ x 3⅝	1⅝ x 5½	1⅝ x 7½	1⅝ x 9½
Nominal size	4 x 4	4 x 6	4 x 8	4 x 10
Actual size	3⅝ x 3⅝	3⅝ x 5½	3⅝ x 7½	3⅝ x 9½
Nominal size	6 x 6	6 x 8	8 x 8	8 x 10
Actual size	5½ x 5½	5½ x 7½	7½ x 7½	7½ x 9½

d. **Parts of a frame structure.** It is essential that the construction draftsman be familiar with the nomenclature and function of the various members. There are three principal types of framing for light structures: balloon, braced, and western. The **Western** or platform method, which includes some of the best characteristics of the other types but minimizes the need for skilled workmen, is the method generally used in military structures. The principal wood members are the joists (horizontal framing), studding (vertical framing), and rafters (roof support). The framing is doubled around openings for stairs, doors, and windows. Figure

4-15 illustrates structural framing (western method) and gives the parts of a light frame structure. All of these parts do not appear in every building, and different materials may be used for some of the parts.

e. **Symbols.** Because of the small scale ⅛" = 1'-0" or ¼" = 1'-0" used on construction drawings it is necessary to use symbols since it is not possible to show actual details. Walls and partitions are shown by parallel lines drawn to represent their thickness (fig 4-19). Some symbols for doors are shown in figure 4-20; notice that single lines show the direction of opening or swing. Figure 4-21 illustrates the symbols for showing various styles of windows. Symbols for wood are included in figure 4-18; notice the distinction between section, finish (exterior), and rough (block) symbols. Figures 4-16 and 4-17 are general detail drawings. These figures show the wall section and the roof truss for the TO building shown in figure 7-3, and illustrate wood detailing practice.

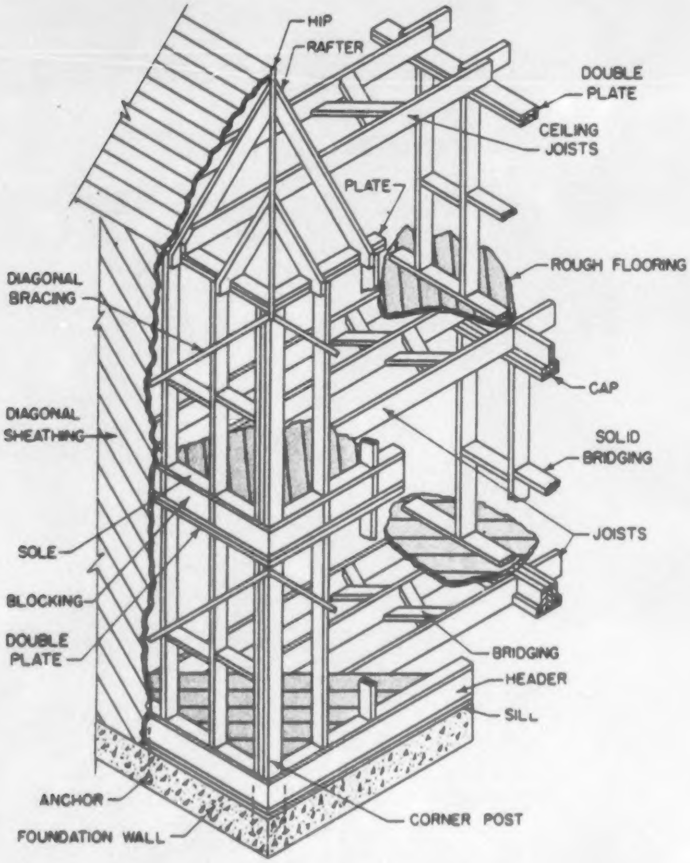

HIP
RAFTER
DOUBLE PLATE
CEILING JOISTS
PLATE
ROUGH FLOORING
DIAGONAL BRACING
CAP
DIAGONAL SHEATHING
SOLID BRIDGING
JOISTS
SOLE
BLOCKING
DOUBLE PLATE
BRIDGING
HEADER
SILL
ANCHOR
CORNER POST
FOUNDATION WALL

Figure 4-15. Western (or platform) framing nomenclature.

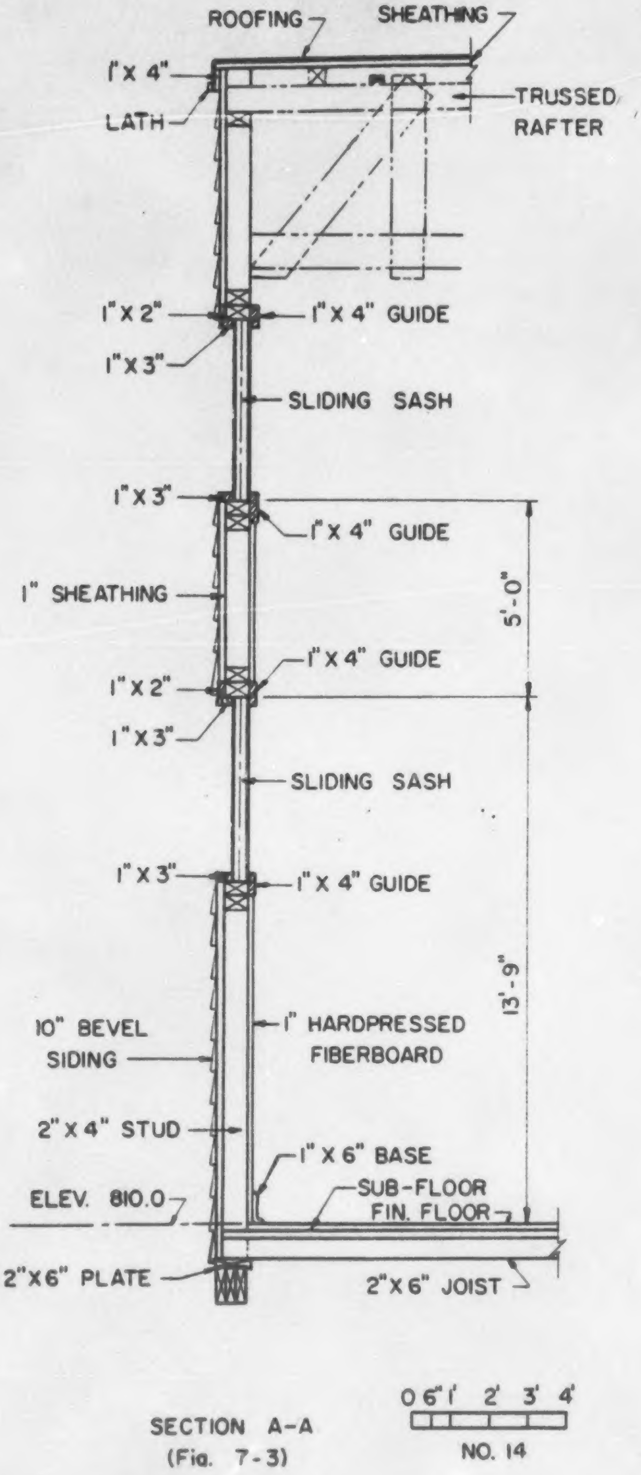

ROOFING
SHEATHING
1"X 4"
LATH
TRUSSED RAFTER
1"X 2"
1"X 4" GUIDE
1"X 3"
SLIDING SASH
1"X 3"
1"X 4" GUIDE
1" SHEATHING
5'-0"
1"X 4" GUIDE
1"X 2"
1"X 3"
SLIDING SASH
1"X 3"
1"X 4" GUIDE
13'-9"
10" BEVEL SIDING
1" HARDPRESSED FIBERBOARD
2"X 4" STUD
1"X 6" BASE
ELEV. 810.0
SUB-FLOOR
FIN. FLOOR
2"X6" PLATE
2"X 6" JOIST
SECTION A-A
(Fig. 7-3)
0 6" 1' 2' 3' 4'
NO. 14

Figure 4-16. Typical wall section detail (see figure 7-3).

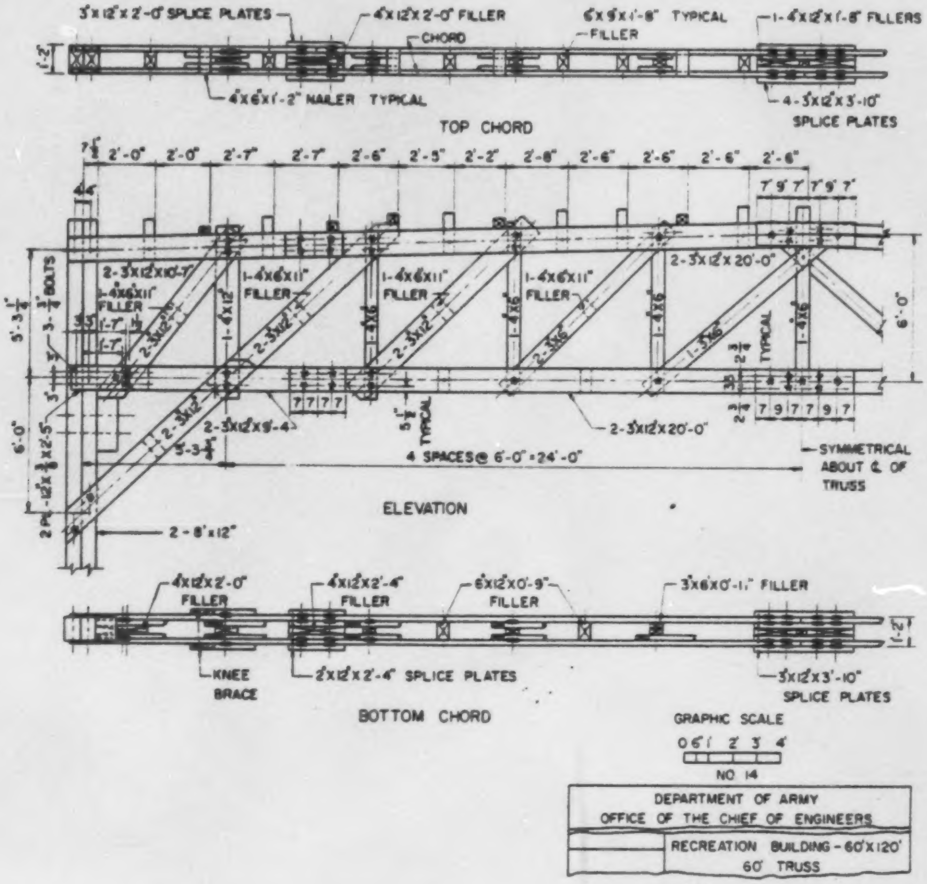

3"x12"x2'-0" SPLICE PLATES
4"x12"x2'-0" FILLER
CHORD
6"x9"x1'-8" TYPICAL
FILLER
1-4"x12"x1'-8" FILLERS
1'-2"
4"x6"x1'-2" NAILER TYPICAL
4-3"x12"x3'-10"
SPLICE PLATES
TOP CHORD
7½" 2'-0" 2'-0" 2'-7" 2'-7" 2'-6" 2'-5" 2'-2" 2'-8" 2'-6" 2'-6" 2'-6" 2'-6"
4½
7 9 7 7 9 7
2-3"x12"x10'-7"
1-4"x6"x11" FILLER
1-4"x6"x11" FILLER
1-4"x6"x11" FILLER
1-4"x6"x11" FILLER
2-3"x12"x20'-0"
1-4"x12"
1-4"x6"
1-4"x6"
1-4"x6"
1-4"x6"
2-3"x12"
2-3"x12"
2-3"x12"
2-3"x6"
1-3"x6"
5'-3¼"
3-¾" BOLTS
1'-7"
1'-7"
6'-0"
TYPICAL
2¾
7 7 7 7
7 9 7 7 9 7
2-3"x12"x9'-4"
5¼" TYPICAL
2-3"x12"x20'-0"
5'-3¾"
4 SPACES @ 6'-0" = 24'-0"
SYMMETRICAL ABOUT ℄ OF TRUSS
6'-0"
2 PL-12"x⅝"x2'-5"
2-8"x12"
ELEVATION
4"x12"x2'-0" FILLER
4"x12"x2'-4" FILLER
6"x12"x0'-9" FILLER
3"x6"x0'-1" FILLER
1'-2"
KNEE BRACE
2"x12"x2'-4" SPLICE PLATES
3"x12"x3'-10" SPLICE PLATES
BOTTOM CHORD
GRAPHIC SCALE
0 6" 1' 2' 3' 4'
NO 14
DEPARTMENT OF ARMY
OFFICE OF THE CHIEF OF ENGINEERS
RECREATION BUILDING - 60'x120'
60' TRUSS

Figure 4-17. Detail of roof truss and roofing.

8. ARCHITECTURAL DETAILS

Architecture, in itself, is based upon the study of fine arts and is beyond the scope of this subcourse; however, the construction draftsman will work with architectural drawings of one sort or another and should, therefore, understand some of the practices employed by the architect. Such parts which cannot be shown in sufficient definiteness on the small-scale general drawings (see lesson 7) are drawn on larger scale drawings. These include, but are not limited to stair details and detail sections of such items as sills, doors, windows, framing, and so on, required to show both construction and architectural design. Later, as the construction progresses and actual measurements can be taken, the drawings are supplemented by full-size details of moldings and other ornamental millwork.

a. Conventional symbols for building materials, walls, partitions, doors, and windows are illustrated in figures 4-18 to 4-21.

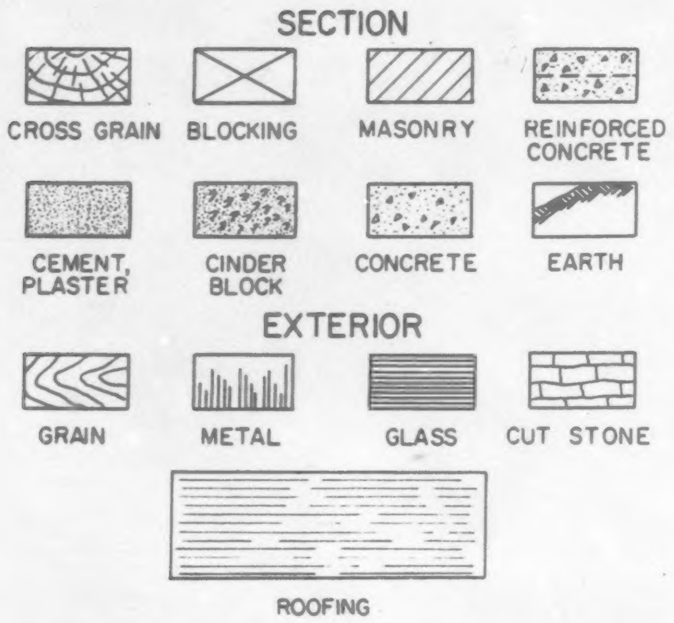

SECTION
CROSS GRAIN
BLOCKING
MASONRY
REINFORCED CONCRETE
CEMENT, PLASTER
CINDER BLOCK
CONCRETE
EARTH
EXTERIOR
GRAIN
METAL
GLASS
CUT STONE
ROOFING

Figure 4-18. Symbols for building materials.

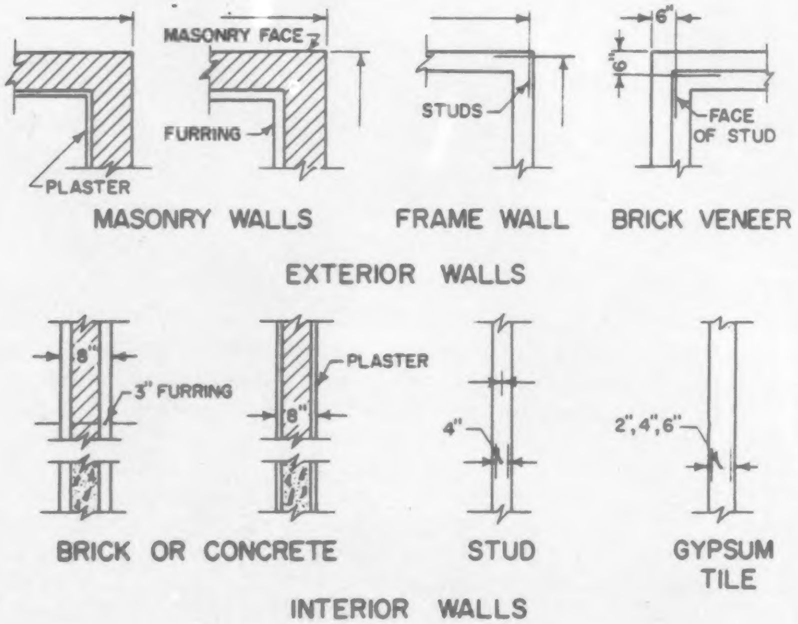

MASONRY FACE
FURRING
PLASTER
STUDS
6"
6"
FACE OF STUD
MASONRY WALLS
FRAME WALL
BRICK VENEER
EXTERIOR WALLS
8"
3" FURRING
PLASTER
8"
4"
2", 4", 6"
BRICK OR CONCRETE
STUD
GYPSUM TILE
INTERIOR WALLS

Figure 4-19. Typical wall symbols.

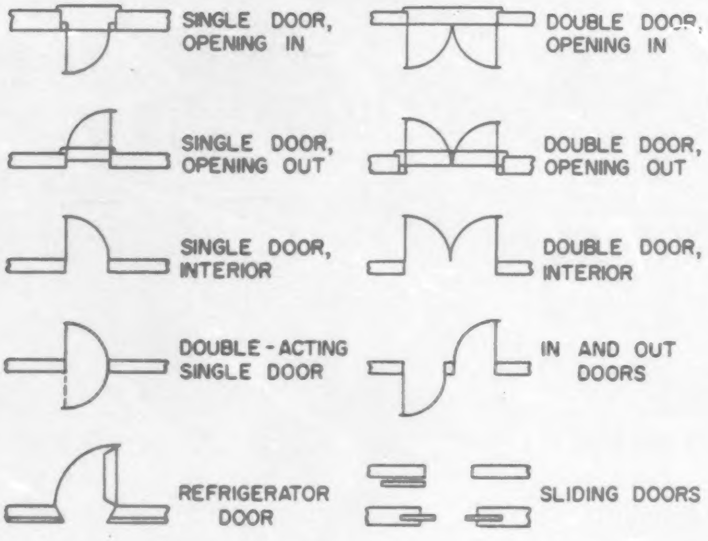

SINGLE DOOR, OPENING IN
DOUBLE DOOR, OPENING IN
SINGLE DOOR, OPENING OUT
DOUBLE DOOR, OPENING OUT
SINGLE DOOR, INTERIOR
DOUBLE DOOR, INTERIOR
DOUBLE - ACTING SINGLE DOOR
IN AND OUT DOORS
REFRIGERATOR DOOR
SLIDING DOORS

Figure 4-20. Typical door symbols.

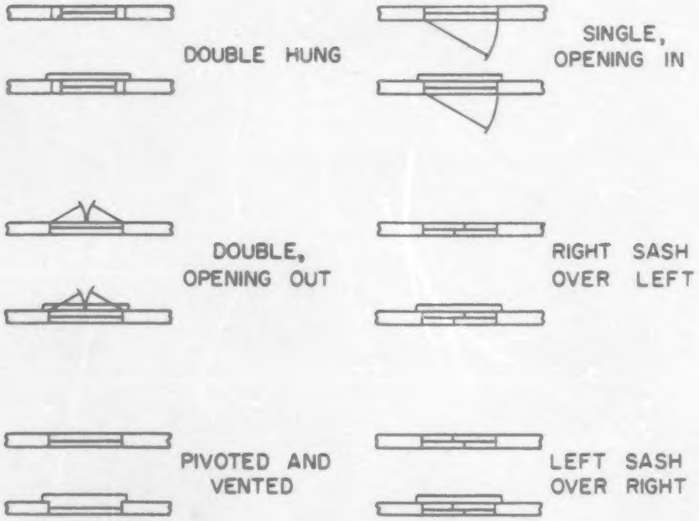

DOUBLE HUNG
SINGLE, OPENING IN
DOUBLE, OPENING OUT
RIGHT SASH OVER LEFT
PIVOTED AND VENTED
LEFT SASH OVER RIGHT

Figure 4-21. Typical window symbols.

b. Sill details. From figure 4-15 it will be noted that the sole plate, or sill, is the horizontal member on which the studs (vertical members) rest. The manner in which it is supported depends on the types of footings or foundations used in the construction of the building. Typical variations of sill details are illustrated in figure 4-22.

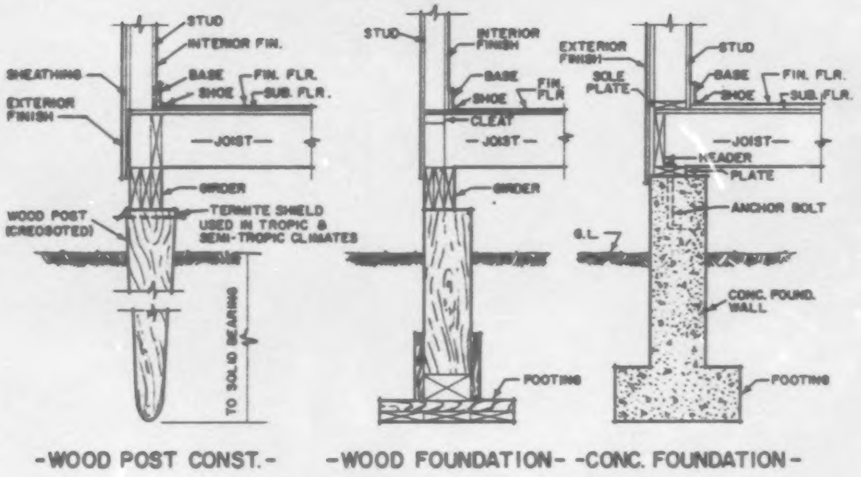
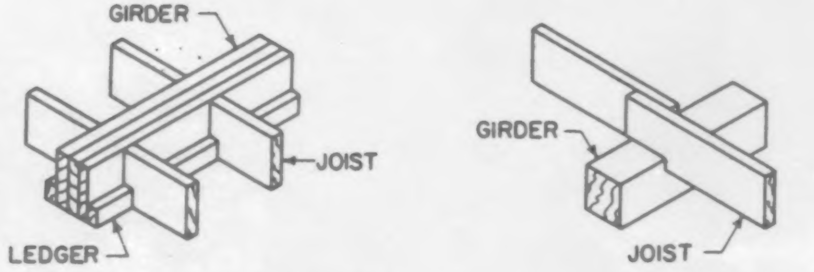
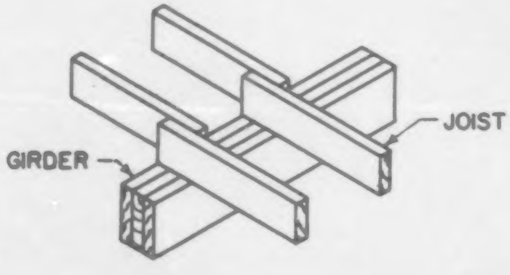

STUD
INTERIOR FIN.
SHEATHING
BASE
FIN. FLR.
SHOE
SUB. FLR.
EXTERIOR FINISH
JOIST
GIRDER
WOOD POST (CREOSOTED)
TERMITE SHIELD USED IN TROPIC & SEMI-TROPIC CLIMATES
TO SOLID BEARING
STUD
INTERIOR FINISH
BASE
SHOE
FIN. FLR
CLEAT
JOIST
GIRDER
FOOTING
EXTERIOR FINISH
STUD
SOLE PLATE
BASE
FIN. FLR.
SHOE
SUB. FLR.
JOIST
HEADER
PLATE
ANCHOR BOLT
G.L.
CONC. FOUND. WALL
FOOTING
-WOOD POST CONST.-
-WOOD FOUNDATION-
-CONC. FOUNDATION-

Figure 4-22. Typical sill details.


GIRDER
JOIST
LEDGER
GIRDER
JOIST

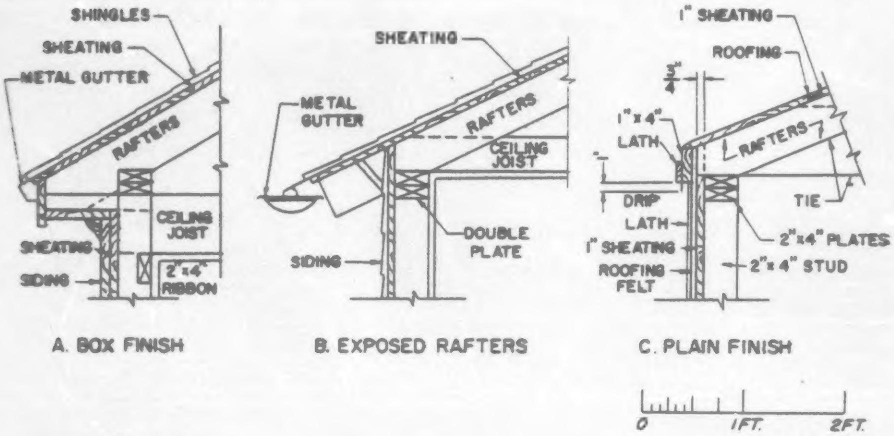
(a) Joists over ledger strips (b) Joists notched over girder


JOIST
GIRDER

(c) Joists over top of girder

Figure 4-23. Girder and joist connections.

c. Girder and joist connections. Joists are connected to sills and girders by several methods. In modern construction, the method that requires the least time and labor and yet gives the maximum efficiency is used. The same rule is followed in the theater of operations. Figure


SHINGLES
SHEATING
METAL GUTTER
RAFTERS
CEILING JOIST
SHEATING
SIDING
2"x4" RIBBON
SHEATING
METAL GUTTER
RAFTERS
CEILING JOIST
DOUBLE PLATE
SIDING
1" SHEATING
ROOFING
3/4"
1"x4" LATH
RAFTERS
DRIP
TIE
LATH
2"x4" PLATES
1" SHEATING
2"x4" STUD
ROOFING FELT
0
1FT.
2FT.

A. BOX FINISH B. EXPOSED RAFTERS C. PLAIN FINISH

Figure 4-24. Cornice details.

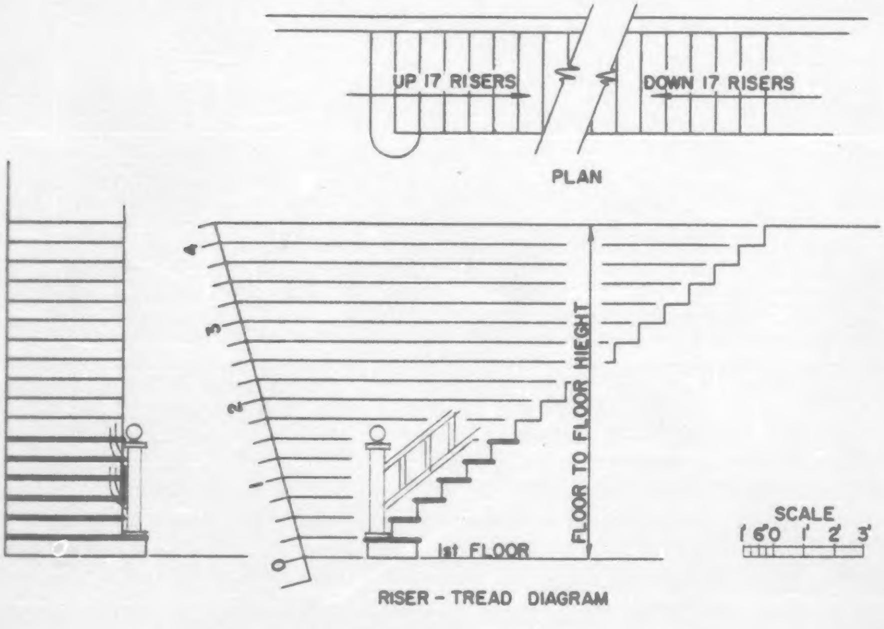

UP 17 RISERS
DOWN 17 RISERS
PLAN
4
3
2
1
0
FLOOR TO FLOOR HIEGHT
1st FLOOR
SCALE
1'6"0 1' 2' 3'
RISER - TREAD DIAGRAM

Figure 4-25. Stairways and steps.

4-23 shows three constructions for girders and methods of supporting the inside ends of floor joists; outside ends of floor joists are supported as shown in figure 4-22.

d. **Cornice details.** The usual roof-framing members are shown and named in figures 4-15 and 4-17. Rafter ends are enclosed with facia boards or wooden cornices. Various methods of cornice construction are illustrated in figure 4-24.

e. **Stairways.** In drawing an inside stairway, a diagram (fig 4-25) is made to determine the number of steps and space requirements. The standard for the riser, or height from step to step, is from 6½ to 7½ inches. The tread width is usually such that the sum of riser and tread approximate 17½ inches (a 7″ riser and 11″ tread is an accepted standard). On the plan the lines represent the edges of the risers and are drawn as far apart as the width of the tread. Notice how the scale may be used to divide the height (floor to floor) into the number of steps. For outside stairs or steps, as for a porch or platform, the risers and treads may vary from the above standard. The type of step most common in field construction is illustrated in figure 4-26.

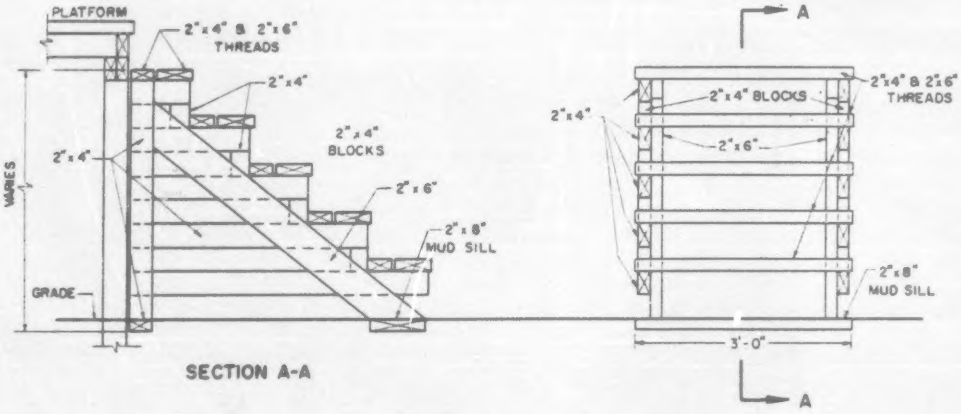


Figure 4-26. Outside steps.

f. **Windows.** Such a wide variety of windows are in use that it is not practical to attempt to show them here. A few contemporary types are: (1) casement, hinged at the sides to swing open, (2) slider, move sideways, and (3) double hung windows, which move up and down usually balanced with cast iron weights. A drawing of a wood sash with nomenclature of parts is illustrated in figure 4-27. Figure 4-28 shows the detail of a typical window for a TO building (fig 7-3).

g. **Doors.** The heights of doors may vary by 2-inch increments from 6′-6″ to 8′-0″, but the usual height is 6′-8″; width may vary from 2′-0″ to 3′-0″, but the standard is 2′-8″. Sizes are indicated as width x height x thickness. An interior door with nomenclature of parts is shown

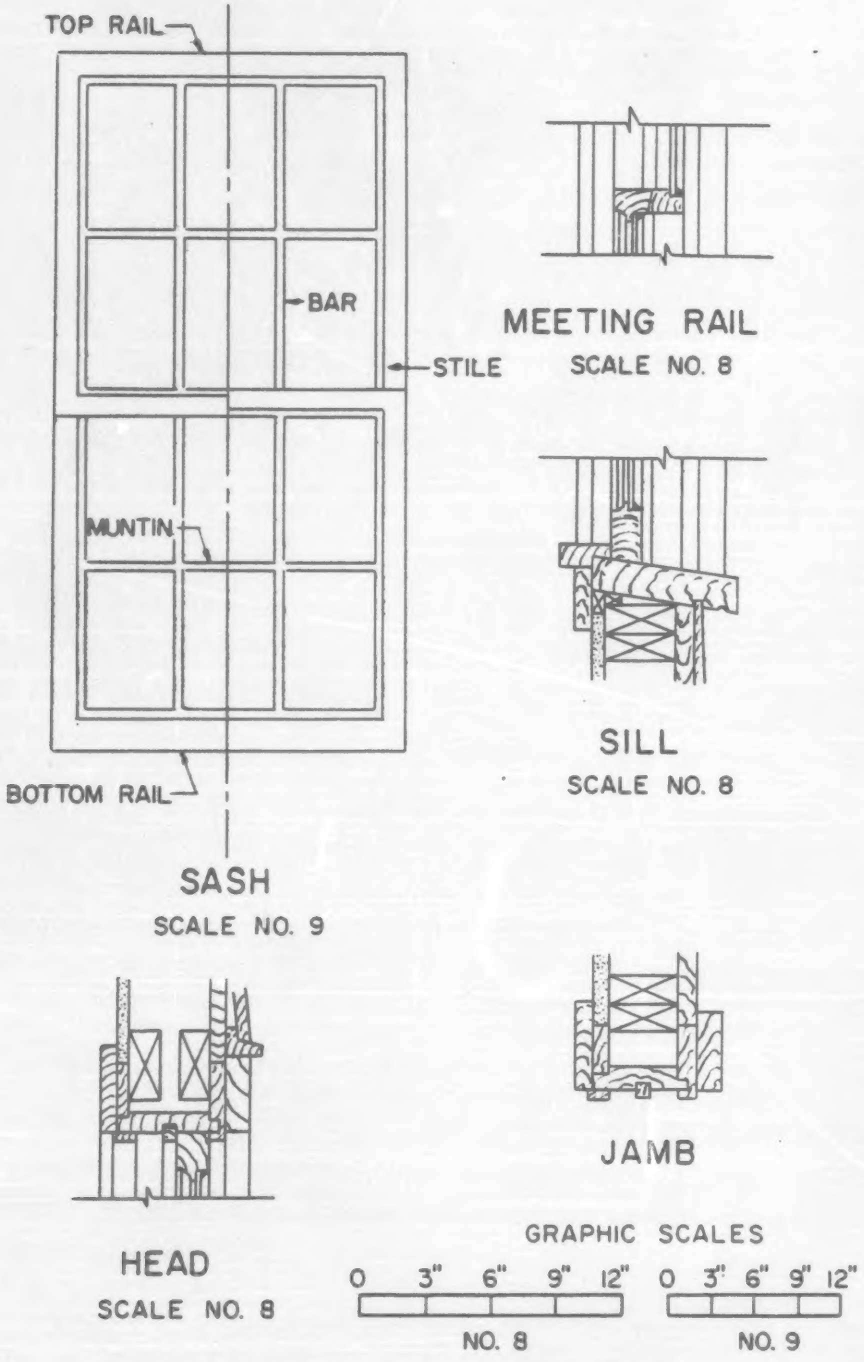

TOP RAIL
BAR
STILE
MUNTIN
BOTTOM RAIL
SASH
SCALE NO. 9
MEETING RAIL
SCALE NO. 8
SILL
SCALE NO. 8
HEAD
SCALE NO. 8
JAMB
GRAPHIC SCALES
0 3" 6" 9" 12"
NO. 8
0 3" 6" 9" 12"
NO. 9

Figure 4-27. Typical wood sash detail.

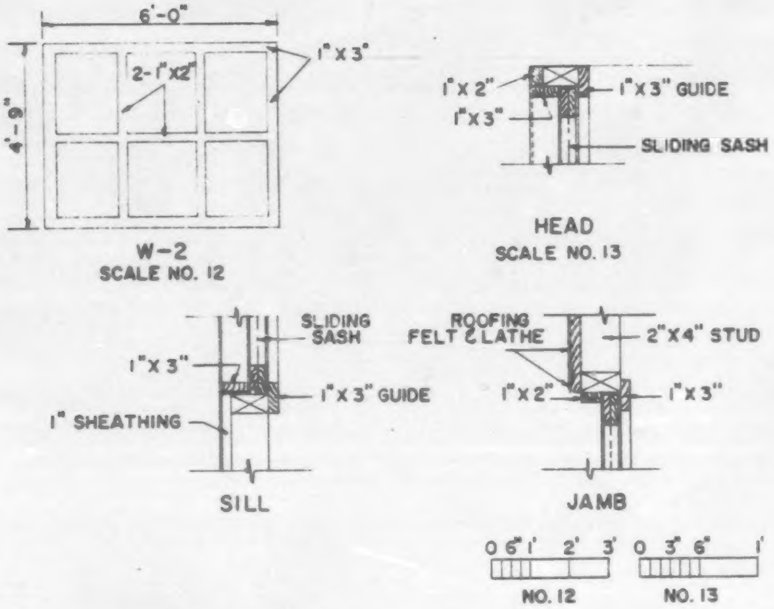

6'-0"
1" X 3"
2-1" X 2"
4'-9"
W-2
SCALE NO. 12
1" X 2"
1" X 3" GUIDE
1" X 3"
SLIDING SASH
HEAD
SCALE NO. 13
SLIDING SASH
1" X 3"
1" X 3" GUIDE
1" SHEATHING
SILL
ROOFING FELT & LATHE
2" X 4" STUD
1" X 2"
1" X 3"
JAMB
0 6" 1' 2' 3'
NO. 12
0 3" 6" 1'
NO. 13

Figure 4-28. Detail of window W2 (see figure 7-3).

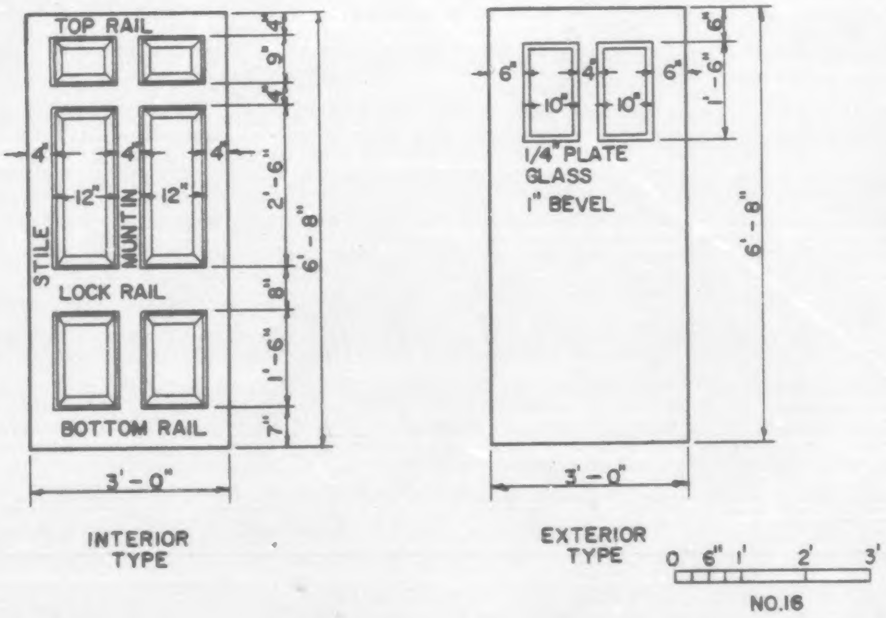

TOP RAIL
4"
9"
4"
4"
4"
4"
12"
12"
2'-6"
6'-8"
STILE
MUNTIN
LOCK RAIL
8"
1'-6"
7"
BOTTOM RAIL
3'-0"
INTERIOR TYPE
6"
6"
4"
6"
10"
10"
1'-6"
1/4" PLATE GLASS
1" BEVEL
6'-8"
3'-0"
EXTERIOR TYPE
0 6" 1' 2' 3'
NO.16

Figure 4-29. Doors.

at A in figure 4-29, and an exterior door is shown at B. Figure 4-30 shows the detail of a typical door for a TO building (door D2, fig 7-3).

Notice how figures 4-28 and 4-30 are titled and given a code (capital letter and number) in order that each detail can be identified on plan and elevation drawings (fig 7-3 and 7-4). Also note that the scale of each detail is indicated with the detail subtitles.

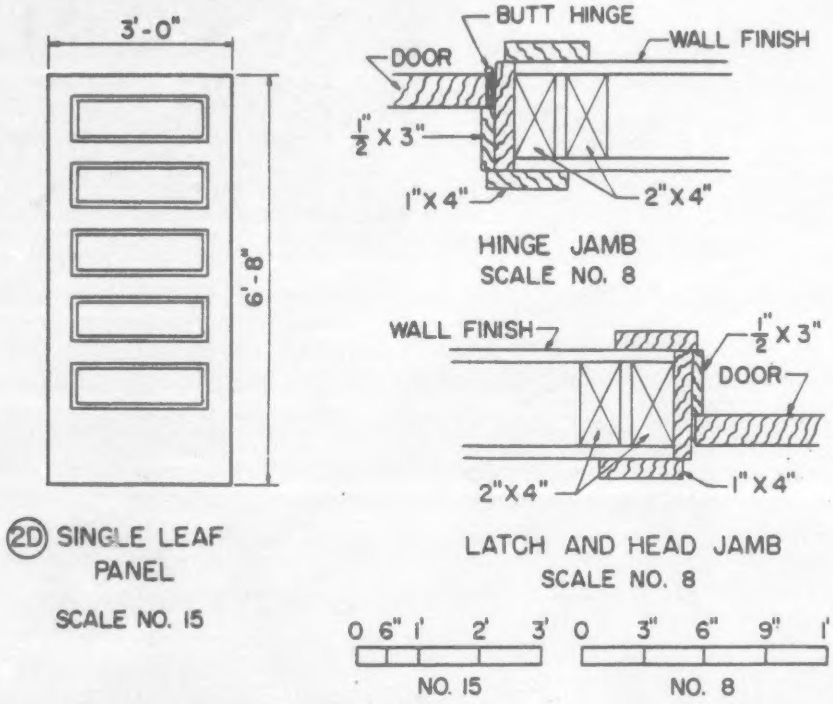

3'-0"
6'-8"
2D SINGLE LEAF PANEL
SCALE NO. 15
BUTT HINGE
WALL FINISH
DOOR
½" X 3"
1" X 4"
2" X 4"
HINGE JAMB
SCALE NO. 8
WALL FINISH
½" X 3"
DOOR
2" X 4"
1" X 4"
LATCH AND HEAD JAMB
SCALE NO. 8
0 6" 1' 2' 3'
NO. 15
0 3" 6" 9" 1'
NO. 8

Figure 4-30. Detail of door 2D (see figure 7-3).

9. ASSEMBLY DRAWING

Throughout the discussion of detail practices emphasis was made concerning the coding and identification of parts and their relative position in a machine or structure. Since the purpose of the assembly drawing is to show the location of the detailed parts in relation to each other, it is of utmost importance that all detailed parts be identified on the assembly.

a. Identification of parts. As illustrated in figure 4-1, parts in a machine are identified on the assembly drawing by numbers used on the details. An alternate method is to letter the name of the part and notes for each part and draw a leader pointing to it in the main view. The making of general drawings (plans, elevations, framing) for structural and architectural drawing has been made the subject of lesson 7, and the methods of cross reference to details will be found therein.

b. Checking. It is to be remembered that assembly drawings can be traced from the design assembly drawing, but more often they are redrawn to a smaller scale from the dimensions of the detail drawing (Engineering Drawing I). This redrawing, being done from both the design and details, offers an excellent check which frequently reveals errors. Hence, the assembly should always be completed prior to acceptance of the details as final.

10. PRACTICE WORK

This practice work will enable you to determine just how well you understand the relation between detail and assembly drawings, and the procedures for making them. Check your answers with the solutions at the back of the booklet. Restudy the attached memorandum where necessary. DO NOT send in your answers to these exercises.

First requirement. Exercise 1 is designed to give you practice in drawing details in accordance with prescribed practices.

1. **Plate I** shows a plan view and section of a stairway opening. You are required to complete the riser-tread diagram showing the number of risers and the space required for a standard 18″ rise and tread. Complete the plan view. DO NOT submit this practice sheet.

Second requirement. The following ten exercises are true or false. If you believe a statement is true check "T", if false or only partly true check "F".

2. The general procedures for making working drawings are applicable in making detail and assembly drawings. T F
3. The most common practice in machine drawing is to make different drawings for each using shop. T F
4. Only one scale, usually ¼″ = 1′-0″, should be used in any one view in making a shop drawing of a structural member. T F
5. The use of an assembly mark makes it possible to identify like structural shapes without repeating the complete specification note. T F
6. The shapes and sizes of reinforcing bars are shown by the usual orthographic representation. T F
7. The abbreviation S2S in a bill of material for lumber specifies the surfacing or amount of planning to be done by the mill. T F
8. Balloon framing is generally employed in military construction because its use minimizes the need for skilled carpenters. T F
9. Architectural details of ornamental millwork are generally based on actual measurements taken as construction progresses. T F

10. A stairway constructed with a 7¼-inch riser and a 10¼-inch tread meets the standard requirements for stairway design. T F

11. Part names and notes with leader lines pointing to each part is an alternate method of identifying machine parts on an assembly drawing. T F

EXERCISES

First requirement. Exercise 1 will enable you to put into practice what you have learned about structural steel details. Follow the instructions carefully; your work will be graded on neatness, layout, completeness, and accuracy.

1.

On plate J make a shop drawing of the beam B12 for the steel frame construction shown in figure 4-10.

This drawing is to be similar to the drawing shown in figure 4-8. All rivets to be 7/8" with 15/16" holes; let gage = 2 1/2 inches and pitch = 2 inches for field connection of 6 x 4 angles to 16 WF 78 columns. Distinguish between shop and field rivets. Use ¼" = 1'-0" for beam length and 1" = 1'-0" for section details. Show all applicable dimensions, erection and assembly marks.

Second requirement. Solve multiple-choice exercises 2, 3 and 4 to show that you understand mechanical detail practices.

2.

How many systems are employed in making detail drawings of machine parts?

a. one
b. two
c. three
d. four

3.

The multiple-drawing system employed in machine drawing requires that each drawing:

a. must have the same scale
b. show an assembly view of the part
c. be cross-referenced, one to another
d. includes three orthographic views

4.

In the single-drawing system the mechanical practice is that:

a. information required by each shop be given separately
b. separate drawings be made for each using shop
c. each drawing be cross-referenced to all other drawings
d. all dimensions be related to a single base line

Third requirement. Multiple-choice exercises 5 through 8 concern the practices followed in making structural steel details.

5.

What is the flange width and thickness of a structural member identified as 16WF78 x 18′-0″?

a. 7; 7/16	c. 8 1/2; 5/8
b. 7; 1/2	d. 8 5/8; 7/8

6.

What is nominal size of the structural member specified in exercise 5?

a. 16 x 6	c. 16 x 8½
b. 16 x 7	d. 16 x 11½

7.

A column may be drawn in a horizontal position on the drawing, in which case:

a. it is drawn with the bottom at the left
b. it is drawn as a beam
c. only one scale is necessary
d. it is drawn symmetrical about its center

8.

Details of intermediate connections and rivet spacings are sometimes shown on shop drawings:

a. without regard to scaled length
b. when the scale is such that they can be shown in true size
c. if only the plan view is required
d. simply by a specification note

Fourth requirement. Solve multiple-choice exercises 9 through 12 to show what you have learned about reinforced concrete details.

9.

Reinforcing bars perpendicular to the section are represented on section details by:

a. heavy dashed lines	c. round or square dots
b. typical shapes	d. the symbol for steel

10.

The shipping mark for a ⅞-inch bent reinforcement bar with an overall length of 16′-8″ is:

a. 1687	c. 70168
b. 7168	d. 78168

11.

The "length" column of a reinforcement schedule lists the:

a. overall length
b. details to outside lengths
c. stretchout length
d. segment length

12.

Bar-bending details listed in reinforcement schedules are illustrated by:

a. diagrammatic symbols
b. abbreviated notes
c. shipping marks
d. length diagrams

Fifth requirement. Multiple-choice exercises 13 through 18 will enable you to show your understanding of wood construction details.

13.

Which of the following abbreviations identifies the classification of a wood used most frequently in construction?

a. PLYWD
b. RGH
c. T & G
d. LLYP

14.

Which of the following grades of lumber are both suitable for use when the finish is to be painted?

a. A and B
b. A and C
c. B and C
d. C and D

15.

In bills of material, lumber to be dressed on four sides, is listed by the abbreviation:

a. SOFS
b. S4S
c. DOFS
d. D4S

16.

The actual size of a 2 x 4 used for studding is:

a. 1⅝ x 3⅝
b. 2 x 4
c. 1⅝ x 4
d. 2 x 3⅝

17.

The swing or direction of opening of doors is shown by:

a. an arrow
b. a single line
c. door schedules
d. section details

18.

The purpose of a detail code is to aid in identification of the detail on the following related drawing:

a. profile
c. orthographic
b. section
d. plan

Sixth requirement. Multiple-choice exercises 19, 20 and 21 pertain to architectural details and assembly drawing.

19.

In theater of operations construction the method of connecting joists and sills is usually the one that requires the least time and labor and yet:

a. saves material
c. results in maximum efficiency
b. permits use of local materials
d. employs simplicity of design

20.

The standard width and height of doors is:

a. 2′-0″ x 6′-6″
c. 2′-10″ x 7′-0″
b. 2′-8″ x 6′-8″
d. 3′-0″ x 8′-0″

21.

An assembly drawing frequently reveals errors in details and should therefore be:

a. carefully traced from the design assembly
b. redrawn from both the design and detail drawings
c. redrawn to a smaller scale from the detail dimensions
d. completed before accepting the details as final

LESSON 5

INTERSECTIONS AND DEVELOPMENTS

CREDIT HOURS __________3

TEXT ASSIGNMENT ______Attached memorandum.

MATERIALS REQUIRED ____Drafting kit and plates K, L, M, N.

LESSON OBJECTIVE ______To teach you how to find the intersection of two geometric surfaces and how to draw all surfaces of an object in their "rolled-out-flat" form.

SUGGESTIONS __________Refer to the suggestions made for lesson 1.

ATTACHED MEMORANDUM

1. DEFINITIONS

A **plane** is a flat surface in which any two points could be joined by a straight line which lies entirely in the surface.

A **curved** surface is a surface no part of which is a plane surface.

A **solid** object is a portion of space which is completely enclosed by plane or curved surfaces, or a combination of planes and curved surfaces.

A **ruled surface** is a surface which can be ruled or generated by a straight line moving in a prescribed manner.

A straight line which moves along a plane curve while remaining parallel to a fixed line generates a **cylindrical** surface.

> The moving line is called a **generatrix**, the curve is called a **directrix**, and any one position of the generatrix is called an **element.**

A straight line which moves so that it always intersects a closed plane curve while passing through a fixed point not in the plane of the curve, generates a **conical** surface.

> If the closed curve is a polygon, the surface generated is a **pyramidal** surface. The fixed point is called a **vertex.** Two conical or pyramidal surfaces are generated, one on each side of the vertex, called **nappes.**

If two surfaces intersect, the line joining all points common to both surfaces is called the **line of intersection.**

A **development** is the complete surface of an object showing its true size and shape when opened and unfolded or rolled out flat in a single plane.

The surfaces of some objects cannot be developed and are said to be **non-developable.** The surface of a sphere cannot be developed.

When one nappe of a pyramid or a cone is cut by a plane parallel to its base and cutting all elements, the solid thus formed is called the **frustum** of a pyramid or cone.

The frustum of a prism or a cylinder has the same shape as the whole prism or cylinder, and hence requires no additional definition.

When one nappe of a pyramid or a cone is cut by a plane not parallel to its base and cutting all elements, the solid thus formed is called a **truncated pyramid** or **cone.**

When a prism or a cylinder is cut by a plane not parallel to its base and cutting all elements, the solid thus formed is called a **truncated prism** or **cylinder.**

2. INTERSECTIONS

It is necessary to find the line of intersection of two surfaces before the surfaces can be developed. In general the problem is one of finding the line of intersection of two solid geometrical shapes or objects. When both objects have shapes which consist of plane surfaces, the solution is most elementary, because the intersection of two non-parallel planes is a straight line, the intersection of a line not parallel to a plane and

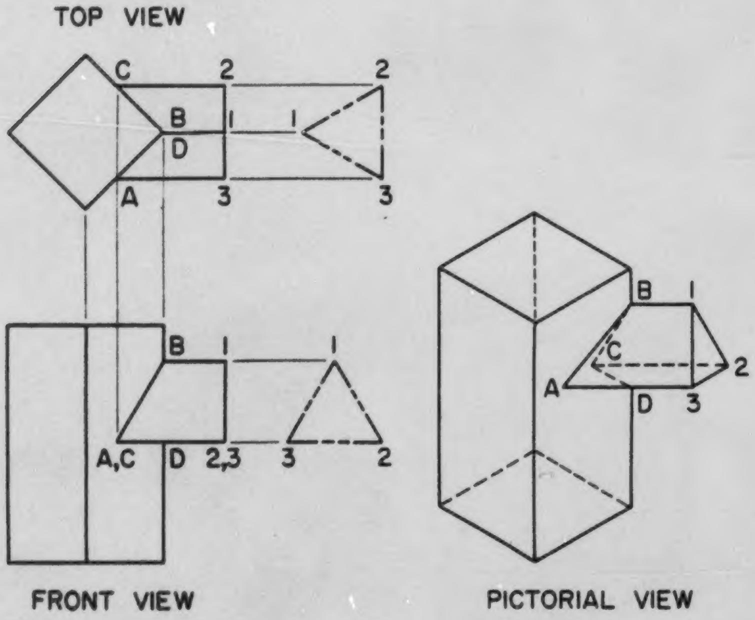


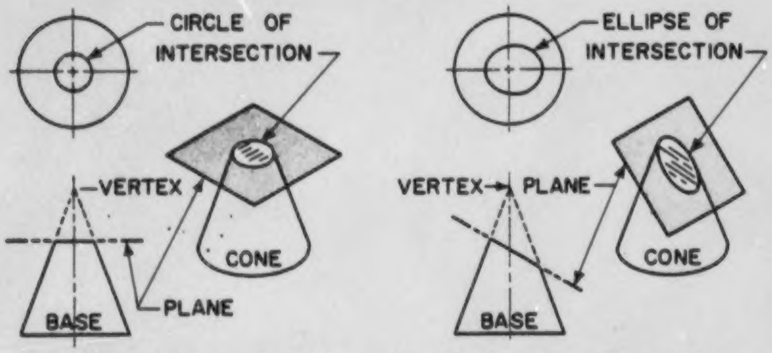
Figure 5-1. Intersection of two objects with plane surfaces.

the plane is a single point, and a straight line is determined by any two points on the line.

a. Two objects having plane surfaces. Study figure 5-1 which illustrates the case of a right triangular prism intersecting a right rectangular prism. A pictorial view is shown to aid in the visualization of the problem. The procedure is as follows:

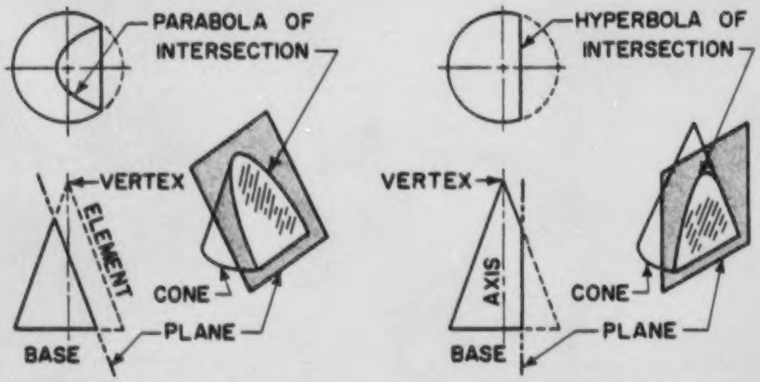
(1) Draw two related orthographic views. The top and front views were selected in figure 5-1. The side view could be used instead of either top or front views, but a third orthographic view is not necessary.

(2) It may be helpful to sketch an end view of the triangular prism as shown by △ 1, 2, 3 in figure 5-1. The edges of the triangular prism in the top view intersect the faces of the rectangular prism in points A, B, C, and D. Project points A, B, C, D to front view and extend the edges of the triangular prism in the front view, thus locating the points A, B, C, and D.


CIRCLE OF INTERSECTION
VERTEX
CONE
PLANE
BASE
ELLIPSE OF INTERSECTION
VERTEX
PLANE
CONE
BASE

A. Cutting plane parallel to base

B. Cutting plane not parallel to base


PARABOLA OF INTERSECTION
VERTEX
ELEMENT
CONE
PLANE
BASE
HYPERBOLA OF INTERSECTION
VERTEX
AXIS
CONE
PLANE
BASE

C. Cutting plane parallel to element

D. Cutting plane parallel to axis

Figure 5-2. Conic sections.

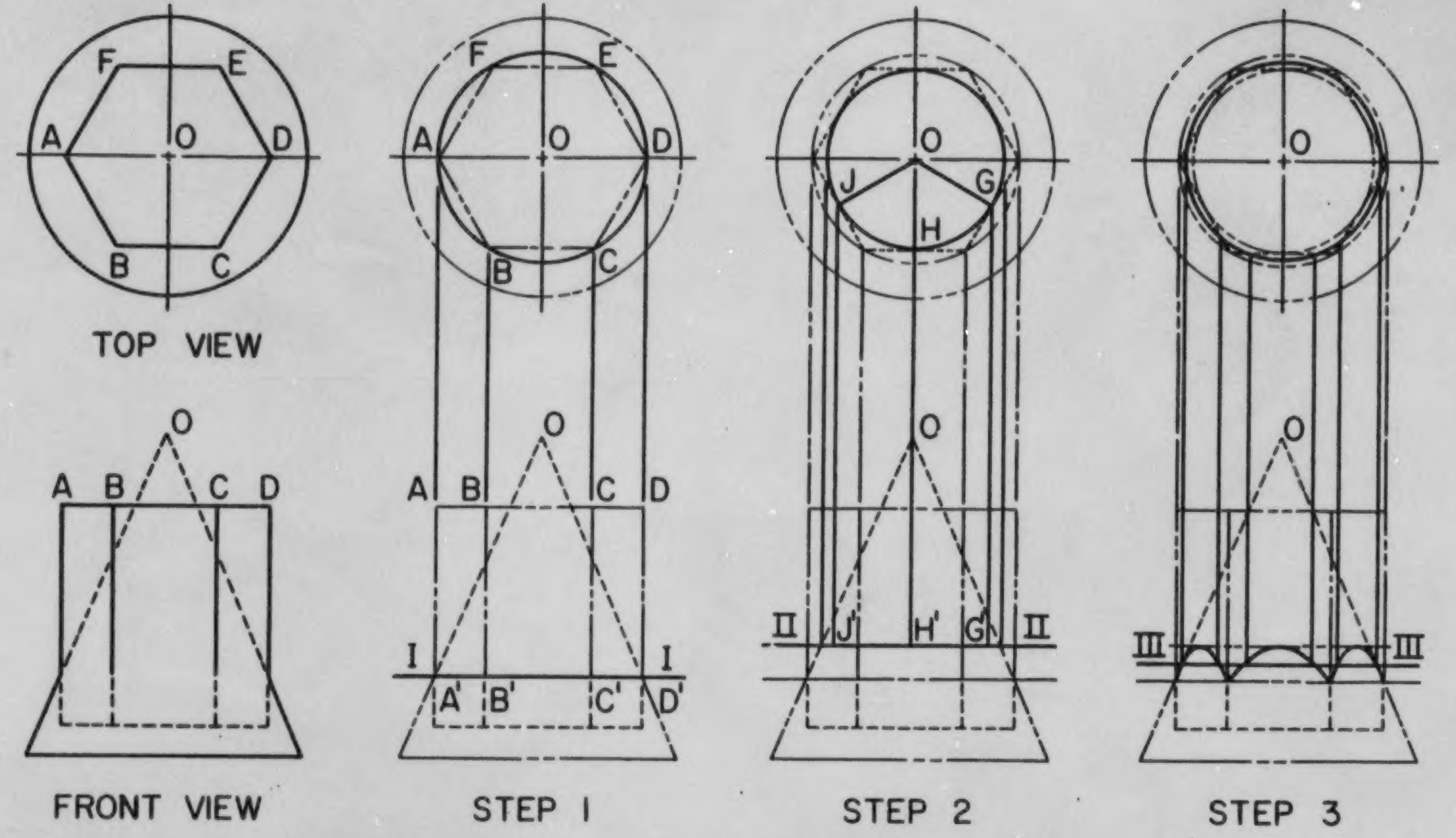

F
E
A
O
D
B
C
TOP VIEW
O
A
B
C
D
FRONT VIEW
F
E
A
O
D
B
C
O
A
B
C
D
I
I
A'
B'
C'
D'
STEP I
O
J
G
H
O
II
J'
H'
G'
II
STEP 2
O
O
III
III
STEP 3

Figure 5-3. Intersection of a regular hexagonal prism and a right circular cone.

(3) Connect points A and B in front view. Hidden edges BC, CD, and AD are underneath the visible lines.

b. One object with plane surfaces and one with curved surfaces. When one object having plane surfaces intersects an object with curved surfaces, the line of intersection is a curved line. Figure 5-2 illustrates some of the various intersections which may result from the intersection of a plane and a right circular cone. If the plane is parallel to the base and cuts all elements of the cone, the intersection is a circle (A-fig 5-2). If the plane is not parallel to the base and cuts all elements, the intersection is an ellipse (B-fig 5-2). If the plane is parallel to an element of the cone, the intersection is a parabola (C-fig 5-2). If the plane is parallel to the axis of the cone it cuts both nappes, and the intersection is a hyperbola (D-fig 5-2). Some special cases not shown are a point, a single straight line, and two intersecting straight lines.

Figure 5-3 illustrates the intersection of a regular hexagonal prism and a right circular cone. Each face of the prism will cut the cone in a hyperbola (D-fig 5-2) and the intersection will be a series of six hyperbolic curves joined end to end. Two related orthographic views are necessary in order to plot points on the intersection. In figure 5-3 the top and front views are used. The top view shows the regular hexagonal prism A, B, C, D, E, F centered at O the vertex of the cone. The procedure for plotting points on the intersection is as follows:

(1) In the top view draw a circle circumscribing the hexagon. Project the points A and D, the ends of the diameter, to the front view where the projection lines meet the side elements of the cone at A′ and D′. Draw cutting plane I-I, which is the circle on edge, through A′ and D′. Also project points B and C to the points B′ and C′ on the plane I-I. The intersection of a plane parallel to the base of a cone is a circle as shown at A in figure 5-2.

(2) In the top view inscribe a circle within the hexagon. Project this circle to the front view by projecting the end points of its diameter to the side elements of the cone, where it appears on edge as the cutting plane II-II. Also mark the points G, H, and J, the points where the inscribed circle is tangent to the faces of the prism, in the top view, and project points G, H, and J to the points G′, H′, and J′ on the plane II-II, thus locating the high points of each hyperbolic curve.

(3) In the top view draw a circle approximately halfway between the inscribed and circumscribed circles. Project this circle to the front view where it appears on edge as the cutting plane III-III. In top view find points where the last circle drawn intersects the sides of the prism and project these points to the plane III-III thus locating two more points on each curve.

(4) Using a French curve, draw the hyperbolic curves through the points located in (1), (2), and (3). These curves are visible outlines, and take precedence over the identical curves formed by the other three sides DE, EF, and FA of the prism.

c. Both objects have curved surfaces. When two objects having curved surfaces intersect, their line of intersection is an irregular curve, which must be plotted by passing a series of construction planes cutting

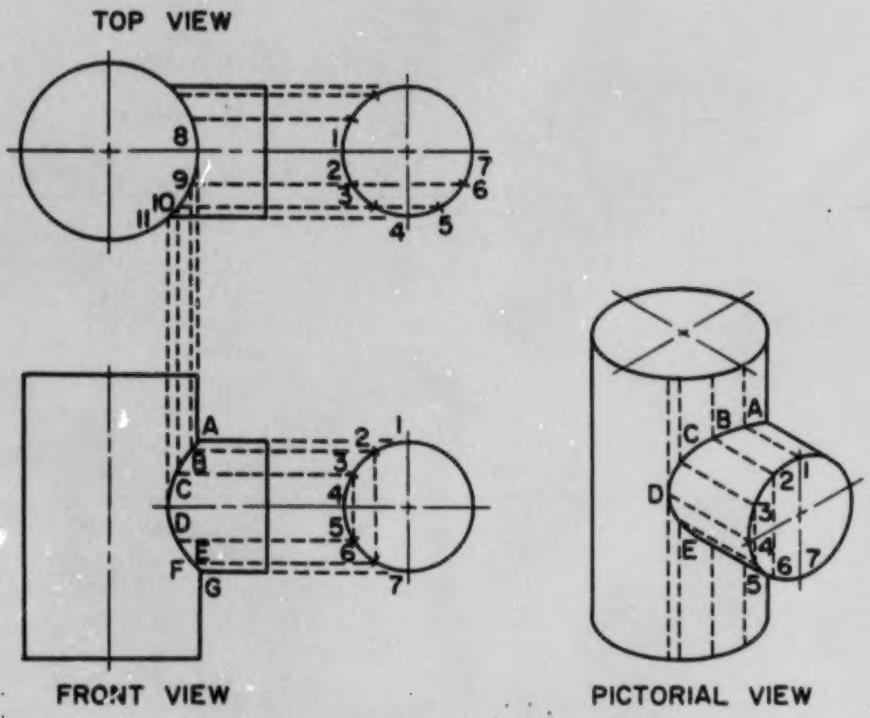


Figure 5-4. Intersection of two cylinders.

each object. Two orthographic views are selected, and points on the intersection are determined by projection between the two views. Figure 5-4 illustrates the steps in plotting the intersection of two cylinders, as follows:

(1) A series of construction planes are passed through both cylinders parallel to their centerlines.

(2) The first plane through the centerlines of both cylinders cuts the small cylinder in elements numbered 1 and 7, and the large cylinder in element numbered 8.

(3) When these elements are projected to the front view they intersect in points lettered A and G.

(4) The second plane parallel to the first, cuts the small cylinder in elements numbered 2 and 6, and the large cylinder in element numbered 9.

(5) When these elements are projected to the front view they intersect in points B and F.

(6) Likewise the plane through elements 3 and 5 on the small cylinder and element numbered 10 on the large cylinder, intersect in the front view in points C and E.

(7) The plane tangent to the small cylinder in element numbered 4 cuts the large cylinder in element numbered 11, and these elements intersect in point D.

A French curve is used to draw the line of intersection through points A, B, C, D, E, F, and G.

3. DEVELOPMENTS

After the intersection of two objects is determined it is sometimes necessary or desirable to draw the surfaces in their unfolded or rolled-out-flat condition. Many objects have regular geometric shapes and their surfaces may be subdivided into plane shapes. The drawing of the development of an object may be thus reduced to a graphical addition of

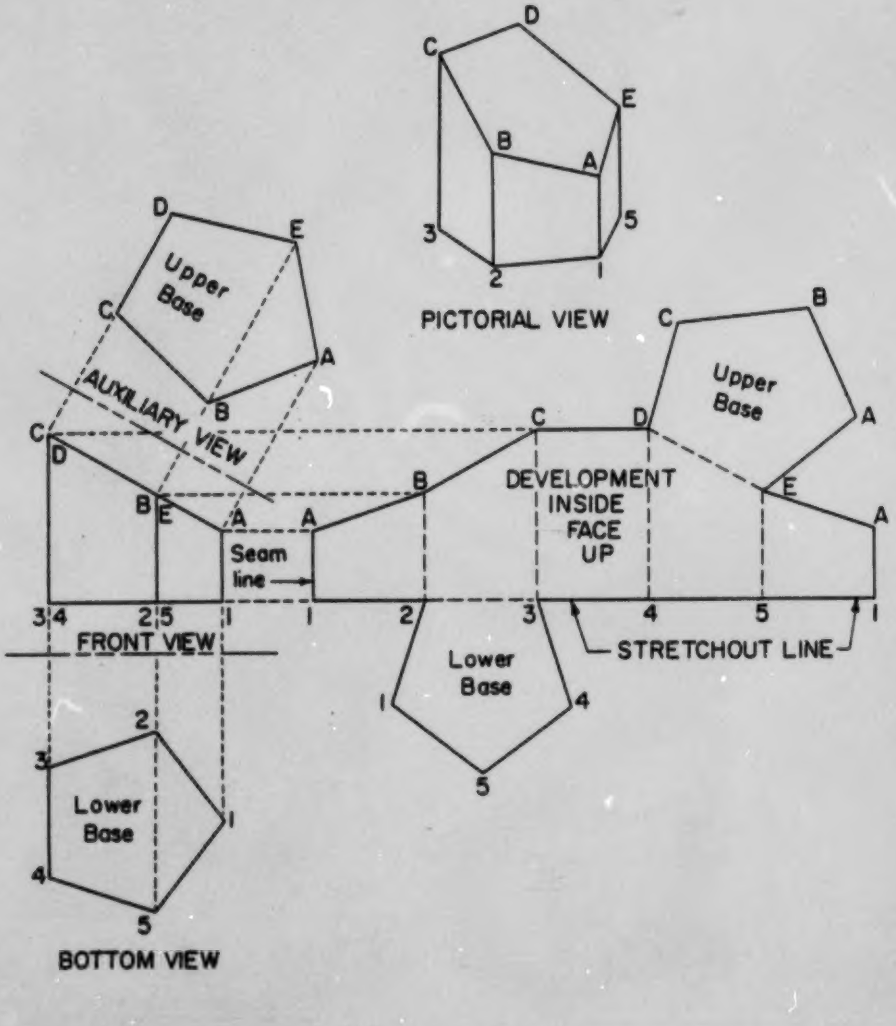

D
C
E
B
A
3
5
2
1
PICTORIAL VIEW
D
E
Upper Base
C
A
B
AUXILIARY VIEW
C
D
B
E
A
A
Seam line
3 4
2 5
1
1
FRONT VIEW
2
3
1
4
5
Lower Base
BOTTOM VIEW
C
B
Upper Base
A
C
D
E
B
A
DEVELOPMENT INSIDE FACE UP
2
3
4
5
1
STRETCHOUT LINE
Lower Base
1
4
5

Figure 5-5. Development of a truncated pentagonal prism.

various plane shapes which can be rolled or folded into the shape of the given object. Fold lines are shown as dotted lines. Developments are drawn as though the surface is unfolded with the **inside** of the surface showing **face** up.

a. **Plane surfaces.** When a solid has all of its surface areas made up of plane figures, the development is made by constructing the surface areas in the same sequence in which they must be when the development is unfolded. It is necessary to select which edges will be cut for opening, and which edges will be fold or bend lines when the development is unfolded. Usually the cut lines are taken as the shortest lines in order to save time and material in making seams. Figure 5-5 shows the development of a regular pentagonal prism, cut by a plane ABCDE not parallel to the base making it a truncated prism. The procedures are:

(1) Draw a stretchout line or base line and measure off five equal spaces, equal to the edges of the base pentagon.

(2) Draw vertical construction lines at each point (1, 2, 3, 4, 5, and 1) measured off in step 1 along the stretchout line.

(3) Locate points lettered A, B, C, D, E, and A by projection from the front view to the vertical construction lines drawn in step 2, and join these points using a straightedge.

(4) Draw auxiliary view, to find true size and shape of the upper base (top), and draw bottom view (lower base) of the prism.

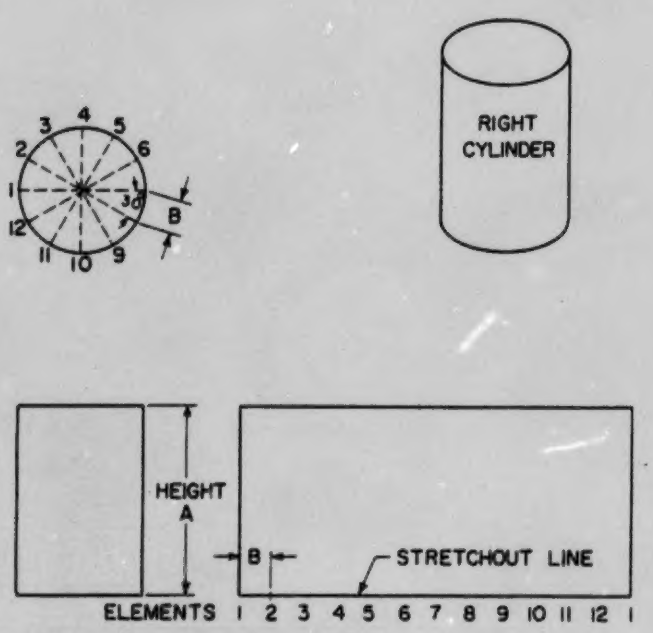


Figure 5-6. Development of a right circular cylinder.

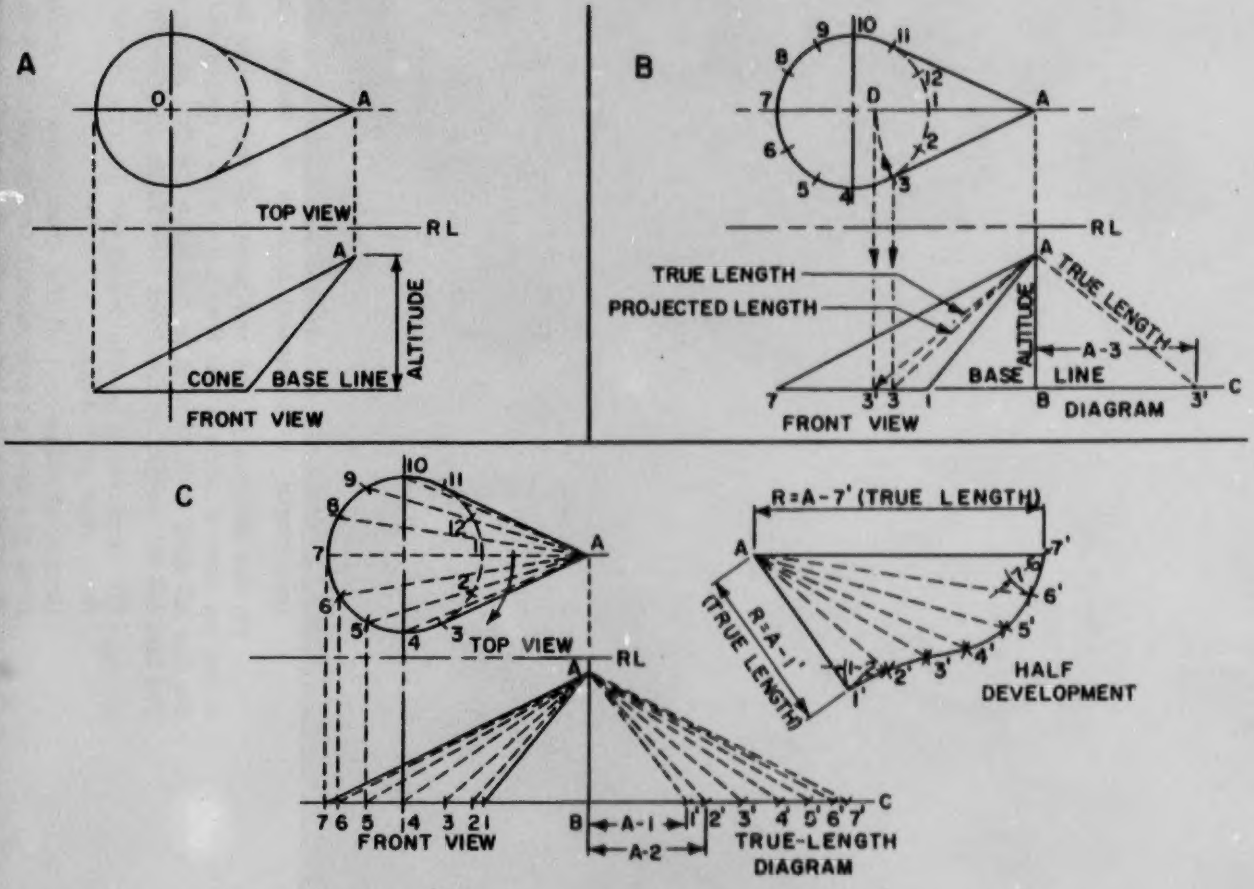

A
O
A
TOP VIEW
RL
A
ALTITUDE
CONE
BASE LINE
FRONT VIEW
B
10
9
11
8
12
7
D
1
A
6
2
5
4
3
RL
A
TRUE LENGTH
PROJECTED LENGTH
TRUE LENGTH
ALTITUDE
A-3
BASE
LINE
C
7
3'
3
1
B
DIAGRAM
3'
FRONT VIEW
C
9
10
11
8
12
7
1
A
2
6
5
4
3
TOP VIEW
RL
A
7 6 5 4 3 2 1
FRONT VIEW
B
A-1
A-2
1' 2' 3' 4' 5' 6' 7'
C
TRUE-LENGTH
DIAGRAM
R=A-7' (TRUE LENGTH)
A
7'
7-6
6'
5'
4'
3'
2'
1-2
1'
R=A-1'
(TRUE LENGTH)
HALF
DEVELOPMENT

Figure 5-7. Constructing a true length diagram.

(5) Draw upper and lower bases by construction in their proper position on the development.

> The pictorial view is shown in figure 5-5 as an aid in visualization of the object.

b. Curved surfaces. Cylinders and cones may be developed in their rolled-out-flat shape by constructing the position of the generatrix at regular intervals and connecting the end points with a straight edge or French curve depending upon the object being developed. Figure 5-6 shows the steps in drawing the development of a right circular cylinder as follows:

(1) Draw the stretchout line for a distance estimated to be slightly longer than the perimeter of the base.

(2) The top view, showing the base of the cylinder, is subdivided into a number of equal parts. The number of subdivisions must be great enough (say 12, or 30° segments) that the length of the chord measured by the dividers is nearly equal to the length of the arc subtended by the chord.

(3) With the dividers set to the length of one subdivision of the base (B), step off the same number of spaces on the stretchout line as stepped off on the perimeter of the base.

(4) Erect perpendiculars at the end points (1 and 1), and mark height A on the development by projection from the front view.

c. True length diagrams. When developing a surface having many oblique lines, it is often more convenient to construct a true length diagram than to draw double auxiliary views. The true length of many lines may then be measured and transferred to the development with dividers. Figure 5-7 illustrates the construction of a true length diagram for the development of an oblique cone. Given the top and front views in block A, to draw the true length diagram and the development, proceed as follows:

(1) Divide the base circle in the top view into a number of equal parts (12 parts are used in block B).

> The point numbered 3 will be used to illustrate how to find the true length of an element such as the oblique line A-3.

(2) Set dividers on the end points of the oblique line, A and 3, in the top view of block B and then with A as a center, swing or rotate the line A3 until it is parallel to the reference line RL in position AD. The line AD will project to the front view in its true length A3′.

> The same result is obtained in the diagram to the right of the front view as follows:
>
> Extend the baseline of the front view a convenient length to C, and drop a perpendicular from vertex A to the baseline at B. With dividers transfer the distance A3 from the top view to the baseline of the diagram, measuring from B to locate the point 3′. Then the distance A3′ in the diagram is the true length of the element A3.

Block C shows how this diagram is used to find the true lengths of the oblique elements of the cone as numbered in the top view. The development consists of constructing a series of adjacent triangles with the true lengths of the elements being taken from the true length diagram, and distances between points 1-2, 2-3, 3-4, and so on, being taken from the base circle in the top view. The points 1′, 2′, 3′, and so on, are joined by using a French curve. Only half of the development is shown in block C.

> Carefully observe that the true length of a line can be found by rotating it into a position parallel to a projection plane, and then projecting its true length on that plane.

4. PRACTICE WORK

Here is another opportunity for you to check your progress. Work the following exercises; then compare your answers with the solutions at the back of the booklet. Restudy the attached memorandum where necessary. DO NOT send in your answers to these exercises.

First requirement. Exercises 1 and 2 are designed to give you practice in locating the intersections of two geometric surfaces and projecting them in rolled-out-flat forms.

1. **Plate K** shows a partially completed drawing of the development and intersection of a regular hexagonal right pyramid with vertex P and a regular right triangle prism ABC. Complete the top and front views showing the intersection in both views, and then draw the development of the pyramid only.

   Use 6H pencil with sharp cone point for construction lines and a 2H pencil to redraw (darken) outlines of completed drawings. You should number all points to check your completed drawing for correctness of intersection and development. DO NOT submit this practice sheet.

2. **Plate L** is a partially completed drawing of the development of a truncated right circular cylinder with centerline at O. You are required to draw an auxiliary view to show the true shape of the upper base, and then draw a development of the cylindrical surface and the bottom base.

   Use 6H and 2H pencils, as in exercise 1. Draw cylindrical surface development with cut line at element numbered 3, and draw bottom base as tangent to stretchout line at point numbered 9. DO NOT redraw upper base attached to the development of the cylindrical surface. DO NOT submit this practice sheet.

Second requirement. The following eight exercises are true or false. If you believe a statement is true check "T", if false or only partly true check "F".

3. A plane is a surface in which any two points can be joined by a line which lies wholly within the surface. T F

4. It is necessary to find the intersection of two objects before drawing the development of their surfaces. T F

5. Developments are usually drawn with the outside of the unfolded surface showing face up. T F

6. A moving straight line which generates a ruled surface is called a generatrix. T F

7. Three orthographic views are required to plot the intersection of two plane surfaces. T F

8. The length of the stretchout line for the development of a right circular cylinder is equal to the diameter of the base. T F

9. It is sometimes possible to obtain the true lengths of lines required for a development without drawing an auxiliary view. T F

10. It is NOT possible to find the intersection of two curved surfaces by two orthographic views. T F

EXERCISES

First requirement. Exercises 1 and 2 are designed to enable you to demonstrate your ability to draw elementary intersections and developments. Follow the instructions carefully. Your work will be graded on neatness, completeness, and accuracy.

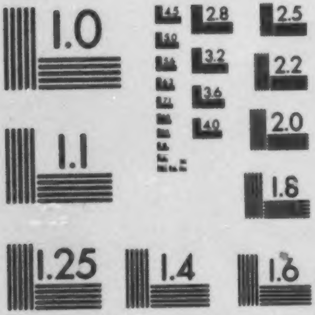
1.

Plate M shows two partially completed orthographic views of the intersection of a right circular cylinder with its centerline at O and a right circular cone with its vertex at P. No dimensions are given or required. The requirement is to draw the line of intersection in the top view, and complete the development of the conical surface and show the line of intersection thereon.

> Use 6H pencil for construction lines and a 2H pencil to retrace outlines when completed. DO NOT erase construction lines. Suggestion: Pass horizontal cutting planes through both the cylinder and the cone. The elements of the cylinder are partially numbered with Arabic numerals, and the elements of the cone are partially numbered with Roman numerals.

2.

Plate N shows two partially completed orthographic views of a right circular cone with apex at P which is cut or truncated by a plane surface A-A. No dimensions are given or required. The requirement is to construct an auxiliary view showing the true size and shape of the upper (truncated) base of the cone, to complete the top view, and using


1.0
4.5
5.0
5.6
6.3
7.1
8.0
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

7.

Before proceeding to draw the development of a surface the draftsman should decide:

a. which edges will be folded lines and which will be cut lines
b. whether to use the isometric or perspective projection
c. the material to be used for building the development
d. how many copies of the development will be required

8.

A right cylinder, which is cut by a plane not parallel to its base is called a:

a. frustum of a cylinder
b. bias cut cylinder
c. truncated cylinder
d. irregular frustum of a cylinder

9.

The intersection in the top view of plate N is:

a. a true ellipse of actual size
b. a true ellipse foreshortened in size
c. a truncated ellipse of true shape
d. an irregular ellipse of true size

10.

The curve of the intersection in the development of Plate M is:

a. a flattened circle not in its true size
b. a stretched out ellipse in its true size
c. an ellipse in its true size
d. an irregular closed curve

11.

On plate M the lines drawn from P to the baseline of the cone in the front view are called:

a. fold lines
b. roll out lines
c. elements
d. stretchout lines

12.

When constructing the development of an object which has many oblique lines it is sometimes helpful to draw:

a. two related isometric views
b. A true length diagram instead of auxiliary views
c. the perspective projection to full scale
d. six orthographic projections showing all six sides

LESSON 6

MACHINE DRAWING

CREDIT HOURS ----------3

TEXT ASSIGNMENT ------Attached memorandum.

MATERIALS REQUIRED ----Drafting kit and plates O, P, Q.

LESSON OBJECTIVE ------To teach you how to draw elementary mechanisms used in the design of machines.

SUGGESTIONS ----------Refer to the suggestions made for lesson 1.

ATTACHED MEMORANDUM

1. INTRODUCTION

A **machine** is an assembly of fixed and moving parts, so related and connected, that it can be used for the conversion of available energy into useful work. A **mechanism** is a subassembly of a machine which is designed to transmit an existing force and motion from one part into the force and motion desired in another part. In simple cases a single mechanism may comprise a machine. Some of the most common mechanisms are:

a. A **driver** is a mechanism which transmits its available force and motion to another mechanism called the **follower.**

b. The follower of one mechanism may be the driver of another.

c. When a driver and a follower are in direct contact it is called a **direct drive** mechanism. If the driver and follower are not in direct contact, the intermediate part is called a link or a band.

d. A **link** is a rigid part capable of transmitting tension or compression forces such as a connecting rod.

e. A **band** is a flexible part which can transmit tension forces only such as a belt or chain.

The purpose of this lesson is to present some of the basic mechanisms which are commonly used in elementary machine design. The draftsman must have a basic understanding of these mechanisms in order to make drawings of machine parts. The designer must know the mathematical relationships involved in the motion of the various parts, whereas the draftsman is more concerned with the instantaneous magnitude and direction of forces, their points of application, or the limits of travel of a moving part.

2. LINKAGES

A linkage is a system of links or bars joined together at pivot points which are fixed or constrained to move in a prescribed path. Only a few of the most elementary and most common linkages will be presented in this lesson.

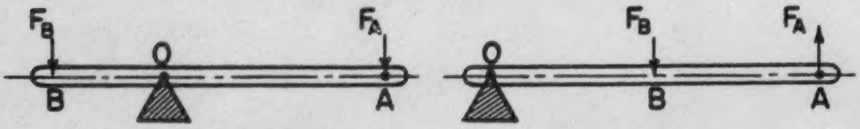


Figure 6-1. Levers.

a. **Lever.** A lever consisting of a single link is a rigid piece free to turn about one fixed point or fulcrum. Figure 6-1 shows two types of levers with the fixed point lettered O, the point A representing the point of application of the driving force F_A, and the point B representing the point of application of the balancing force of the follower F_B. The lever is used to multiply a small force through mechanical advantage or sometimes vice versa. The driving force times its distance from the fulcrum (lever arm) is equal to the balancing force times its lever arm. Thus, referring to figure 6-1, $F_A \times OA = F_B \times OB$ (Eq 6-1)

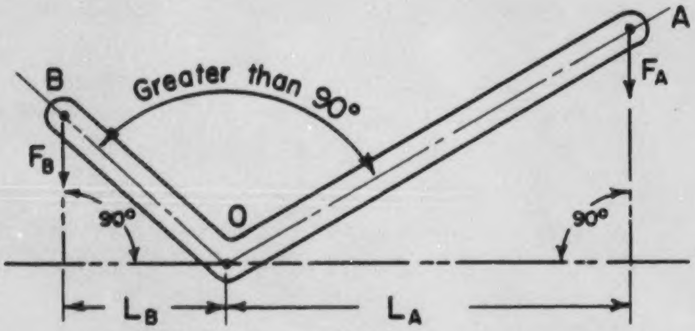


Figure 6-2. Rocker arm.

b. **Rocker arm.** A rocker arm may be considered as a bent lever with its two arms making an obtuse angle (greater than 90°). Figure 6-2 shows a rocker arm with fixed pivot point O and arms OA and OB meeting in an obtuse angle. In this case it is necessary to use the "effective lever arm" in equation 6-1. **Effective lever arm** is the perpendicular distance from the fulcrum to the line of action of the force acting (L_A or L_B). Thus, referring to figure 6-2,

$F_A \times L_A = F_B \times L_B$ (Eq 6-2)

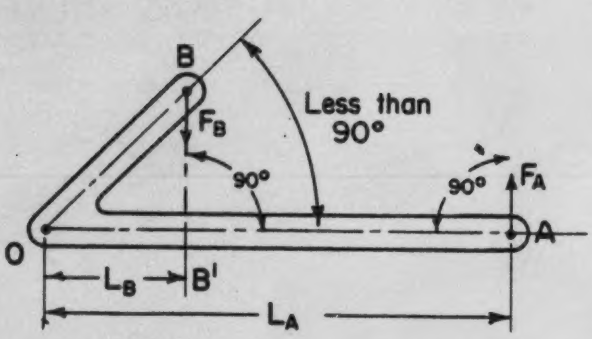


Figure 6-3. Bell crank.

c. **Bell crank.** A bell crank may be considered as a bent lever with its two arms meeting in an acute angle (less than 90°). Figure 6-3 shows a bell crank with a fixed pivot point O and arms OA and OB meeting at an acute angle. In this case it is again necessary to use "effective lever arm" and the equation for the balanced forces is identical with equation 6-2: $F_A \times L_A = F_B \times L_B$

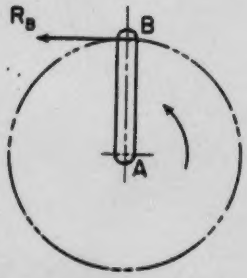


Figure 6-4. Rotating crank.

d. **Rotating crank.** If a link is subjected to a rotational force about a fixed point, the mechanism is called a rotating crank. Figure 6-4 shows a link AB which rotates counterclockwise about a fixed point A. The velocity of the point B at the instant shown is represented by a vector (arrow) R_B. The length of the vector represents the magnitude of the velocity, and the direction of the vector represents the direction of motion of the point B at that instant.

e. **Four-bar linkage.** Figure 6-5 is a schematic diagram of a four-bar linkage showing all links in a zero or starting position. If the driver moves alternately to the left and right through equal angles 1, and 2, the point B_0 will move first to B_1 and then to B_2. The follower will move through angles 3 and 4 in the same periods of time; however careful construction and measurement will show that angles 3 and 4 are unequal. Thus if the driver moves with uniform angular speed, the follower will move with a variable angular speed. Therefore, values of

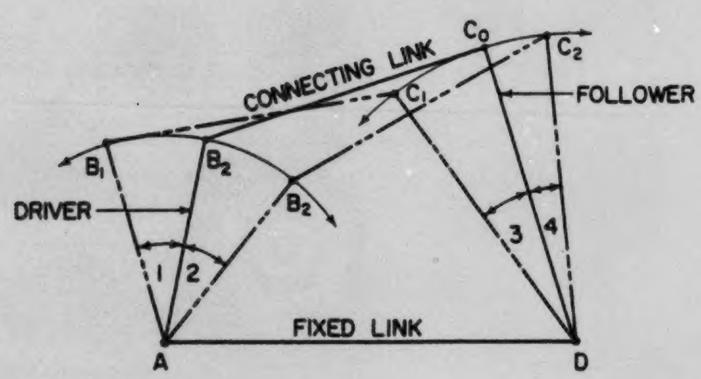


Figure 6-5. Four-bar linkage.

the angular speeds of the driver and follower, and the linear speeds of the moving points B and C for any given arrangement of the linkage, apply only for that instant. When the links have moved to any other position, the quantities involved will have changed to new instantaneous values. (See par 3b.)

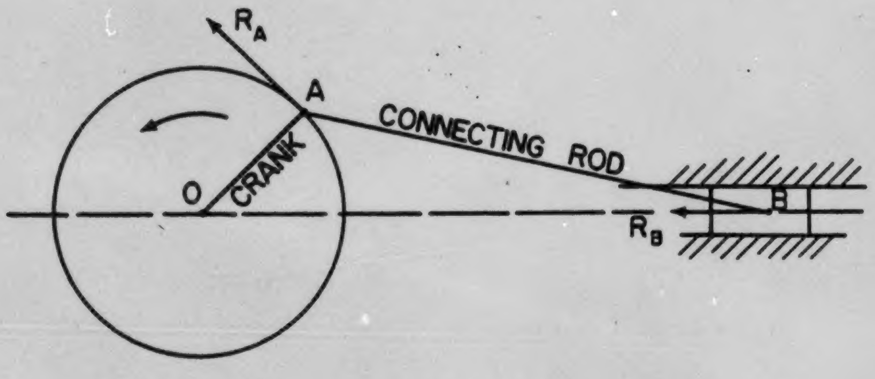


Figure 6-6. Crank and connecting rod.

f. Crank and connecting rod. Figure 6-6 is a diagram of the values of the instantaneous forces for a crank and connecting rod. In this mechanism the reciprocating straight line motion of a sliding block B is converted into the rotary motion of the crankshaft about a fixed center O. The true instantaneous velocities of the points A and B are represented by the vectors R_A and R_B.

g. Resultant motion of a point. A point on the link of a mechanism may be constrained to move in a definite direction, or it may move in a direction which is determined by the action of two or more forces acting on that point. Thus referring to figure 6-7, the instantaneous motion of a point O, acted on by two forces F_A and F_B is represented by a vector F_R which is the vector sum of the two components. The resultant force

F_R is found by constructing a parallelogram with the two components F_A and F_B as sides, and drawing the diagonal to find F_R.

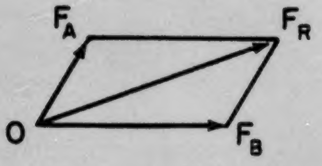


Figure 6-7. Resultant of two forces.

3. STRAIGHT-LINE MECHANISMS

A straight-line mechanism is a linkage which will produce rectilinear motion of a point by constraining it to move in a straight line because of the relative proportions of the links. There are many types of straight-line mechanisms, but only the most elementary types will be presented.

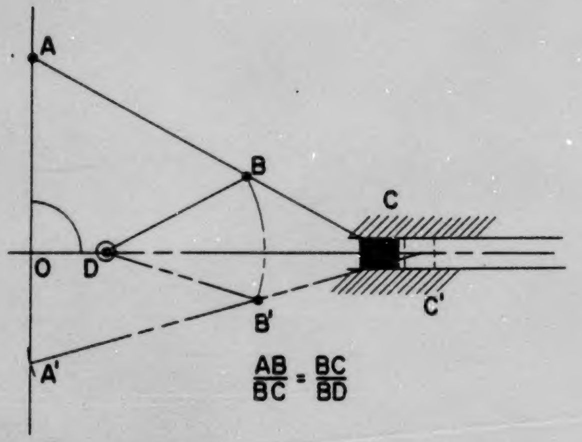


Figure 6-8. Straight line mechanism.

a. Straight-line motion. The linkage shown in figure 6-8 consists of a link DB pivoted at fixed point **D**, and pinned at the point **B** on the link AC, so that lengths AB:BC = BC:BD. If the point **C** is attached to a sliding block constrained to move along the straight line through DC, the point **A** will trace an approximate straight line AA′ as the link DB swings about D. If AB = BC = BD the point A will trace an exact straight line. Algebraically then AB/BC = BC/BD or,

$$AB \times BD = (BC)^2 \qquad \text{(Eq 6-3)}$$

Example 1: In figure 6-8 given AB = 3.6″, and DB = 2.5″ Find the length of BC in inches

Solution: $AB \times BD = (BC)^2 = 3.6 \times 2.5 = 9$

$BC = \sqrt{9} = 3''$ **Ans.**

Example 2: In the figure 6-8 how far from O should the point D of example 1 be located?

Solution: Let the point C move until point A coincides with O. In this position it can be seen that OD = AB - DB. Therefore, OD should be 3.6 - 2.5 = 1.1″ **Ans.**

b. Parallel motion. Parallel-motion mechanisms are not straight-line mechanisms, but are closely related mechanisms. Parallel rulers and the universal drafting machine are examples. These mechanisms are four bar linkages (par 2e) with each pair of opposite sides equal, thus forming a parallelogram. If one side is fixed, the opposite side always moves parallel to the fixed side.

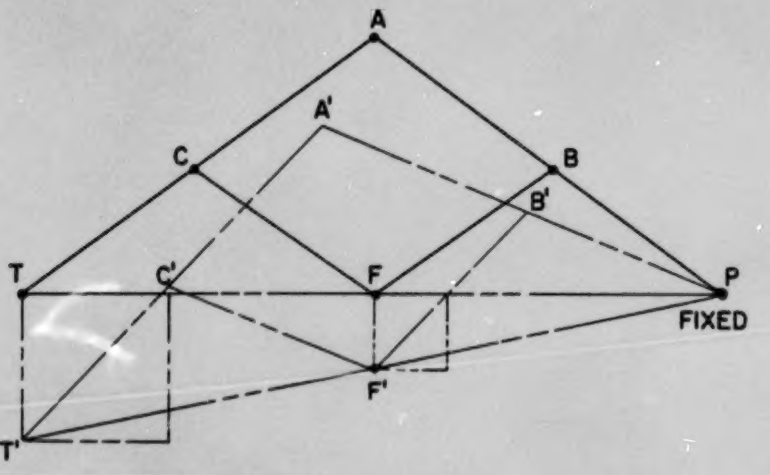


Figure 6-9. Pantograph.

c. Pantograph. The pantograph is essentially a four bar linkage connected to form a parallelogram with two extended sides, and so designed as to make two points move in parallel paths at a predetermined distance ratio. It is used to enlarge or reduce the size of drawings. Figure 6-9 shows one arrangement of the links of a pantograph. The general requirements for the setting of the pantograph links are:

(1) The four bars must be connected to form a parallelogram (ABFC) with two sides extended (ABP and ACT).

(2) The tracing point T, the follower point F, and a fixed pivot P must be on separate links, and lie in a straight line PFT.

(3) The ratio of the distance moved by the tracing point to the distance moved by the follower point is equal to the ratio of their respective distances from the pivot point P.

Example 3: On figure 6-9 the distance TF equals the distance FP. If the follower point moves ½″ downward, how does point T move?

Solution: By reconstructing lihkage as shown by phantom lines, the point T, has moved downward 1″ because TP = 2 × FP.

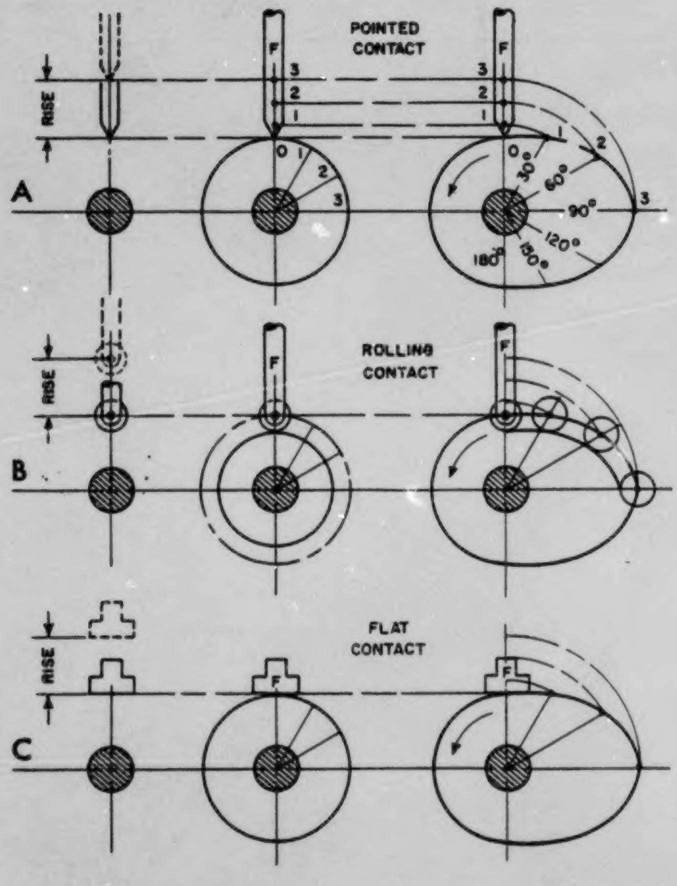


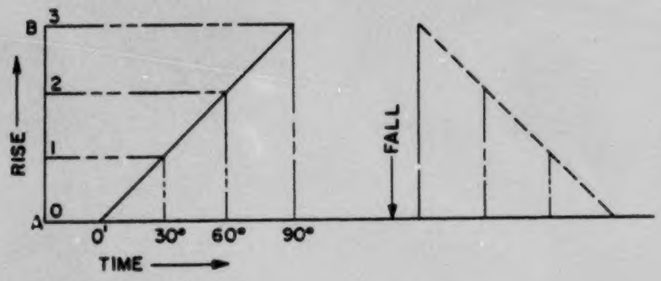
Figure 6-10. Cams and followers.

4. CAMS

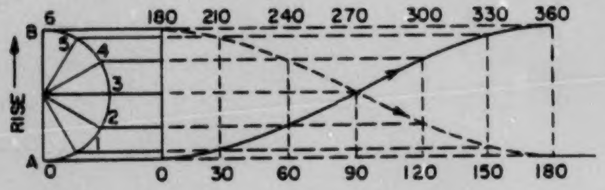
A **cam** is a plate, cylinder or solid piece, with a curved outline or groove, which rotates about an axis and transmits its rotary motion to the reciprocating (up and down) motion of another piece called the **follower.** The follower may have a pointed, rolling or flat contact with the cam, as illustrated in figure 6-10. The (up and down) motion of the follower may be irregular or regular. **Irregular** motion conforms to no definite law. **Regular** motion conforms to some physical law, and may be uniform, harmonic, uniformly accelerated or uniformly retarded with reference to time.

> **Note.** In this lesson it is assumed that the cam and camshaft are turning at a constant speed in revolutions per minute so that equal angles about the center of the cam represent equal periods of time. It is also assumed that the follower is constrained to move in an up and down line of motion only.

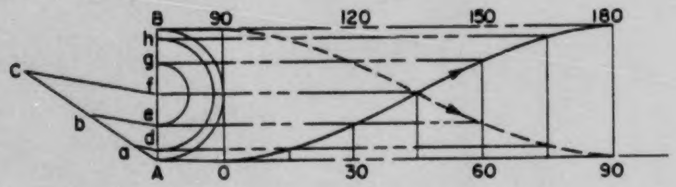
The different kinds of regular motion are best illustrated by plotting the up and down motion (or rise and fall) of the follower for each interval of time, thus making a **motion diagram** (fig 6-11).


B
3
2
1
0
A
RISE
FALL
0°
30°
60°
90°
TIME

1. UNIFORM MOTION


6
180
210
240
270
300
330
360
B
5
4
3
2
1
RISE
A
0
0
30
60
90
120
150
180

2. HARMONIC MOTION


B
90
120
150
180
h
g
C
f
e
b
d
a
A
0
30
60
90

3. UNIFORMLY ACCELERATED AND DECELERATED MOTION

Figure 6-11. Motion diagrams.

a. Uniform motion. If the point of a follower moves equal distances in equal periods of time, the follower has uniform motion. Referring to diagram 1, figure 6-11, the total rise of the follower, represented by AB, is divided into three equal parts. The follower must rise to points

1, 2, and 3 in the time it takes the cam to turn in equal intervals of time to 30°, 60° and 90° respectively. The follower may have uniform fall as shown on the right side of diagram 1.

b. Harmonic motion. Diagram 2, figure 6-11, is the motion diagram for harmonic motion of the follower. The line AB represents the total rise of the follower. Points on the motion diagram are found by dividing a semicircle into 30° sectors, intersecting the semicircle in points numbered from 1 to 6. The numbered points are projected horizontally to the ordinates drawn for equal time intervals of rotation of the cam. The solid curve shows the harmonic "rise" for 180° rotation of the cam, and the dotted curve shows the harmonic "fall" of the follower to its original position. A cam with this motion is useful for high speed operation.

c. Uniformly accelerated and retarded motion. Diagram 3, figure 6-11, represents uniformly accelerated and uniformly retarded motion. The line AB represents the total "rise" of the follower as before. The line AB is halved, and the lower half is divided into three parts in the ratios of 1:3:5. This is done graphically so that $\frac{Ad}{1} = \frac{de}{3} = \frac{ef}{5}$. The upper half of the line AB is divided by using dividers so that $\frac{fg}{5} = \frac{gh}{3} = \frac{hB}{1}$. The solid curve shows the "rise" of the follower by uniform acceleration to the midpoint of travel and its continued rise by uniformly retarded motion. The dotted curve shows the "fall" of the follower to its midpoint of travel, by uniformly accelerated motion and its continued fall by uniformly retarded motion to its original position. Uniformly accelerated motion is the motion of a freely falling body, and it gives the easiest motion to a cam.

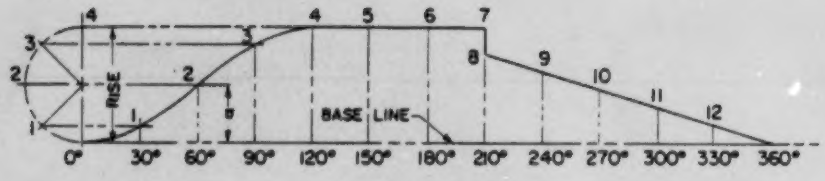
d. Construction of a cam. To develop the design for a cam it is necessary to know the initial position of the follower with respect to the camshaft, the type of contact, the motion required of the follower and the direction of rotation of the camshaft.

Example: Construct a plate cam with a pointed follower to turn counterclockwise. The follower is to move in a vertical line above the center of the cam. In the initial position the follower point is 1 inch above the center of the cam. The follower is required to have the following motions.

0°-120°, rise 1 inch with simple harmonic motion
120°-210°, dwell or rest with no motion
at 210°, drop ¼ inch instantly
210°-360°, fall ¾ inch with uniform motion

Solution: Refer to figure 6-12 and study each step.

(1) Draw baseline of motion diagram and mark off 12 equal spaces along baseline, and number points of 12 equal spaces to represent each 30° interval of rotation of the cam.


4
3
2
1
RISE
1
2
3
4
5
6
7
8
9
10
11
12
a
BASE LINE
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°

MOTION DIAGRAM

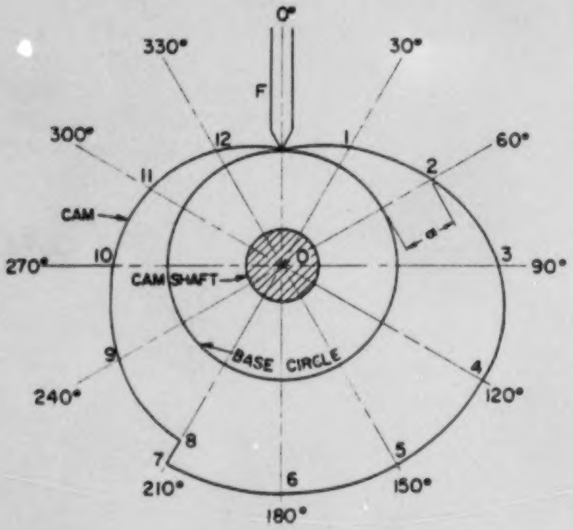

0°
330°
30°
F
300°
60°
12
1
2
11
CAM
a
10
O
3
270°
90°
CAM SHAFT
9
BASE CIRCLE
4
240°
120°
8
7
5
210°
6
150°
180°

Figure 6-12. Construction of a cam.

(2) Draw semicircle at left end of baseline with diameter equal to 1 inch rise and tangent to baseline. Divide semicircle into four equal arcs (at 45° intervals) numbered 1, 2, 3, and 4. The semicircle is divided into four equal arcs because there are four 30° intervals from 0° - 120°. Points 1, 2, 3, and 4 are projected horizontally with T-square to locate points 1, 2, 3, and 4 on the motion diagram. Points 4, 5, 6, and 7 are all on the line 1 inch above baseline because follower rests from 120° - 210°. The point 8 is ¼ inch below point 7 because the follower drops ¼ inch instantly at 210°. From 210° - 360° the follower falls ¾ inch to starting position with uniform motion, and a straight line is drawn from point 8 to the end of the diagram.

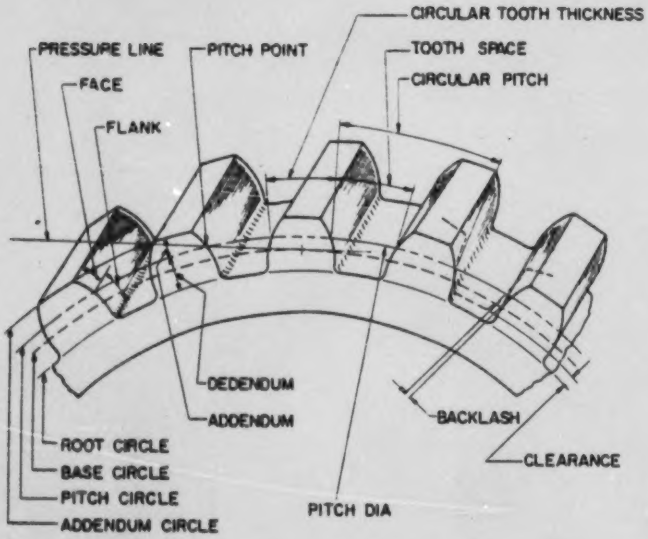
(3) Draw base circle with radius of 1 inch and mark the initial point of the follower at 0° position of the cam. Extend all 30° lines outside base circle.

(4) Locate points on cam by transferring distances of each point above baseline in motion diagram with dividers to same distance outside base circle. See distance "a" for point No. 2 on 60° line.

(5) Connect points 0-1-2-3-4 and 8-9-10-11-12-0 with a French curve. Points 4 through 7 are connected with a curve of 2 inch radius.

5. GEARS

To understand the operation and drawing of gears, first consider two shafts, connected through the rolling contact of two wheels or cylindrical pulleys of equal or different diameters. If one shaft is turned, and there is no slippage at the point of rolling contact of the two wheels, the other shaft will turn in the opposite direction. The speeds of the two shafts will be inversely proportional to the diameters of the two wheels through which they are connected. To prevent slippage when large forces are transmitted, it becomes necessary to cut teeth in each wheel thus forming two gears with meshing teeth. A complete coverage of gears is beyond the scope of this subcourse. Only a few necessary definitions and the steps in drawing spur gear teeth by the approximate circular arc method are presented herewith.


CIRCULAR TOOTH THICKNESS
PRESSURE LINE
PITCH POINT
TOOTH SPACE
FACE
CIRCULAR PITCH
FLANK
DEDENDUM
ADDENDUM
BACKLASH
ROOT CIRCLE
CLEARANCE
BASE CIRCLE
PITCH CIRCLE
PITCH DIA
ADDENDUM CIRCLE

$$\text{DIAMETRAL PITCH} = \frac{\text{NO. OF TEETH}}{\text{PITCH DIAMETER}}$$

Figure 6-13. Gear terminology.

a. Definitions. Figure 6-13 illustrates some of the terminology used in connection with the drawing of gears.

(1) **Pitch circle** is the projection of an equivalent cylinder on a plane perpendicular to the axis of the gear. The pitch circles of two meshing gears are tangent at the **pitch point**, which is on their line of centers.

(2) **Pitch diameter** is the diameter of the pitch circle. Gear teeth are designed to the size of equal subdivisions stepped off on the pitch circle.

(3) **Circular pitch** is the linear distance between corresponding points on two adjacent teeth measured along the pitch circle. The circular pitches of two meshing gears are equal.

(4) **Diametral pitch** is the number of teeth on the gear wheel per inch of pitch diameter.

(5) **Addendum circle,** or outside circle, is the circle which passes through the outer extremities of the teeth.

(6) **Root circle** is the circle which passes through the bottoms of the grooves between the teeth.

> The addendum circle and the root circle are concentric with the pitch circle.

(7) **The addendum distance** of a gear is equal to the radius of the addendum circle minus the radius of the pitch circle.

(8) **The dedendum distance** of a gear is equal to the radius of the pitch circle minus the radius of the root circle.

(9) **Clearance** is the difference between the addendum distance of one gear and the dedendum distance of another gear in mesh with it.

(10) **The face** of a tooth is the portion of the contact surface between the pitch circle and the addendum circle.

(11) The **flank** of a tooth is the portion of the contact surface between the pitch circle and the root circle.

(12) The **circular thickness** of a tooth is its thickness measured along the arc of the pitch circle.

(13) **Tooth space** is the space between two teeth measured on the arc of the pitch circle.

(14) **Backlash** is the difference between the tooth thickness of a gear and the tooth space of another gear in mesh with it.

> Note that the circular thickness of a tooth is equal to the tooth space and that circular pitch is equal to the sum of circular tooth thickness and tooth space.

b. **Gear proportions.** In order for two gears to mesh, the teeth of each gear must fit the space between the teeth on the other. The opposing teeth contact each other along a common "pressure line". The pressure angle between the pressure line and the line of centers of the two gears, determines the shape of the tooth face. The American Standards Association has standardized two pressure angles, 14½° and 20°. The draftsman uses 15° (or 75° tangent to base circle) as a close approximation for the pressure angle. The dimensions necessary to draw an American standard 14½° gear are related according to the following mathematical equations.

Name	Symbol	Relationship
Number of teeth	N	
Diametral pitch	P_d	$P_d = N/D$
Pitch diameter	D	
Addendum	a	$a = 1/P_d$
Dedendum	b	$b = 1.157/P_d$
Outside diameter	D_o	$D_o = (N + 2)/P_d = D + 2a$
Root diameter	D_R	$D_R = D - 2b = (N - 2.314)/P_d$
Circular pitch	p	$p = \pi/P_d = \frac{\pi D}{N}$
Circular tooth thickness	t	$t = p/2 = \frac{\pi D}{2n} = \frac{\pi}{2P_d}$

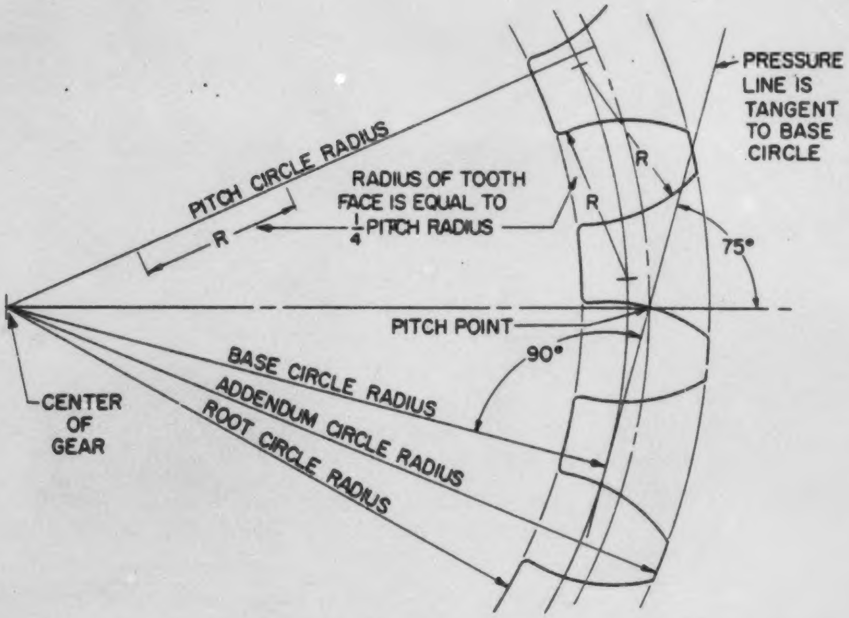

PRESSURE LINE IS TANGENT TO BASE CIRCLE
PITCH CIRCLE RADIUS
R
RADIUS OF TOOTH FACE IS EQUAL TO $\frac{1}{4}$ PITCH RADIUS
R
R
75°
PITCH POINT
90°
BASE CIRCLE RADIUS
ADDENDUM CIRCLE RADIUS
ROOT CIRCLE RADIUS
CENTER OF GEAR

Figure 6-14. Drawing a spur gear.

c. **Steps in drawing a spur gear.** Figure 6-14 illustrates the steps in drawing a spur gear by the approximate circular arc method as follows:

(1) Draw pitch circle, addendum circle and root circle.

(2) Mark pitch point, and divide pitch circle into as many divisions as the number of teeth and subdivide each space in half to represent one tooth plus one tooth space.

(3) Through pitch point draw a line at 75° to the radius of the pitch circle extended. This line represents the **pressure line** or **line of action** of force transmitted to another gear in mesh. Use 30° angle plus 45° angle of triangles to obtain 75° pressure line.

(4) Draw base circle tangent to pressure line. The radius of the base circle is found by sliding one leg of a 90° triangle along the pressure line until the other leg meets the center of the gear. The base circle contains the centers of arcs of tooth faces.

(5) Divide pitch radius into four parts and with compass set to ¼ pitch radius draw faces of teeth through points laid off on pitch circle, keeping centers of arcs on the base circle.

(6) Retrace portions of addendum circle for top of each tooth.

(7) Retrace portions of root circle for bottom of groove between teeth.

6. PRACTICE WORK

This self-test is designed to point up your understanding of the essentials of machine drawing. Check your answers with the solutions at the back of the booklet. Restudy the attached memorandum where necessary. DO NOT send in your answers to these exercises.

First requirement. Exercises 1 through 4 are designed to give you practice in constructing a cam and a gear.

1. The point O on practice plate O marks the center of a plate cam, and points F-F' mark the lowest and highest points of movement for a pointed follower. Draw the motion diagram for the follower, given the following data:

   0° - 90° rise one inch with uniform motion
   90° - 180° dwell or rest
   180° - 270° fall one inch with uniform motion
   270° - 360° dwell or rest

2. On practice plate O, construct a plate cam to turn counterclockwise about the center O for the follower described in exercise 1.

3. The point G on practice plate O marks the center of a gear with its pitch point at P. Considering the gear is to be designed for 40 teeth on a pitch diameter of 10 inches, make the following calculations:

Diametral pitch	P_d
Outside diameter	D_o
Addendum	a
Dedendum	b
Root diameter	D_R
Circular pitch	p
Tooth thickness	t

4. **Next**, on practice **plate O**, draw the pressure line for gear described in exercise 3 at 75° to the horizontal, find radius of base circle by graphical method, and find radius of tooth face. After making calculations draw four teeth, one of which should have its upper face pass through the pitch point "P". DO NOT submit this practice sheet.

Second requirement. The following six exercises are true or false. Check "T" if you believe a statement is true, otherwise check "F".

5. A mechanism may be both a driver and a follower at the same time. T F
6. A link of a chain in a chain drive mechanism transmits compression force only. T F
7. A bell crank and a rocker arm are links. T F
8. A pantograph is a five bar linkage for drawing graphs. T F
9. All regular motion is a form of uniform motion. T F
10. When a large gear operates in mesh with a small gear their circular pitches are equal. T F

EXERCISES

First requirement. Exercises 1, 2, and 3 are designed to enable you to demonstrate your ability to draw elementary mechanisms. Follow the instructions carefully; your completed plates will be evaluated on line weights, completeness, neatness, and accuracy.

1.

Plate P is partially laid out for the design of a plate cam which turns counterclockwise about its center C. The initial position of a point follower is shown at F. The follower is to have the following motions:

0° - 90° rise 1.5 inches with uniform motion
90° - 180° rest with no motion
180° - 360° fall 1.5 inches with simple harmonic motion.

Complete the motion diagrams and plot points for each 30° rotation (except for broken out section 90° - 180°) of the cam. Draw curve of required cam.

Use a 6H pencil for all construction lines and a 2H pencil to retrace object outlines for clarity.

2.

The left side of **plate Q** shows a 7 bar linkage in its initial position. The links AB, BC, CD and DA form a rhombus (a parallelogram of equal sides). Links OP and PC are equal, points O and P are fixed, and all links are free to turn on pinned joints. Draw the complete linkage in phantom lines when point B is moved to point B_1 and when point D is moved to D_2.

Use 6H pencil for all construction lines and 4H pencil to draw phantom lines showing new position of linkage.

3.

The right side of plate Q shows a four bar linkage in its initial position. Links AB, BC, CD and DA are equal; link CB extended is fixed at point P; and link CD extended carries a tracer point at T. The point F on the link AB is a follower point. Draw the complete linkage in phantom lines when the tracer point is moved to T_1 a distance of 1½" and at an angle of 45° to the right of vertical.

Use 6H and 2H pencils in the same manner as for exercise 1.

Second requirement. Solve multiple-choice exercises 4 through 13 to show your understanding of the function of mechanisms, and in particular the methods applied in drawing linkages, followers, cams, and gears.

4.

The distinction between a mechanism and a machine is that:

a. a machine is a subassembly of a mechanism

b. a machine consists of two or more mechanisms

c. all mechanisms are driven by machines

d. mechanisms are subassemblies of machines

5.

When a driver and its follower are not directly in contact the intermediate piece is called a:

a. link if it is a chain drive for compression forces

b. chain if it transmits flexible forces

c. link or a band depending upon type of force transmitted

d. band if it is a rigid connection

6.

A linkage as applied to machine drawing is defined as a:

a. system of rigid bars joined at fixed or movable pivot points

b. series of small links connected to form a continuous chain

c. connection which converts a driver into a follower

d. combination of flexible connections for fixed bars

7.

After drawing the two phantom positions of the 7 bar mechanism of **Plate Q**, it is found that the:

a. point P must be moved to permit movement of B to B_1

b. points A, A_1 and A_2 lie on a straight line

c. point O must be moved to allow D to move to D_2

d. points C, C_1 and C_2 lie on a line parallel to the line B, B_1 and B_2

8.

After drawing the phantom position of the 4 bar linkage of **Plate Q**, the follower point F has:

a. moved ⅓ as far as T, in the same direction

b. moved the same distance as T in the same direction

c. moved ⅓ as far as T in the opposite direction

d. remained fixed to allow point A to move to A_1

9.

Referring to the completed **plate P**, the plate cam between the 90° and 180° position is:

a. elliptical in shape due to follower jumping 90°

b. a straight line because follower is stationary

c. an exact quadrant of a circle to keep follower at rest

d. cut away because motion diagram has a skip in it

10.

Referring to the motion diagrams of **Plate P** the diagram curve for the uniform motion is drawn by a:

a. T-square to make follower same height as the curve

b. French curve to make smooth curve through all points

c. compass because radius of circle is uniform

d. straight edge because it is a straight line

11.

A mechanism which causes the rectilinear motion of its follower point is called a:

a. rectilinear mechanism

b. straight line mechanism

c. parallel motion mechanism

d. driver mechanism

12.

To transmit motion to a follower for high speed operation the cam is designed so that the follower will have:

a. uniform rise and fall

b. uniformly accelerated motion

c. harmonic motion of rise and fall

d. uniformly accelerated and retarded motion

13.

When making a machine drawing of a gear, the circle which is the projection of the equivalent cylinder is called the:

a. circular pitch

b. pitch circle

c. base circle

d. root circle

LESSON 7

ARCHITECTURAL AND STRUCTURAL DRAWING

CREDIT HOURS ----------3

TEXT ASSIGNMENT ------Attached memorandum.

MATERIALS REQUIRED ----Drafting kit and plates R, S.

LESSON OBJECTIVE ------To teach you how to draw elementary architectural and structural drawings.

SUGGESTIONS ----------Refer to the suggestions made for lesson 1.

ATTACHED MEMORANDUM

1. INTRODUCTION

a. Architecture versus engineering. The design of any structure represents close cooperation between architects and engineers. One of the principal factors influencing the design of a structure is its function, that is, the use for which it is intended.

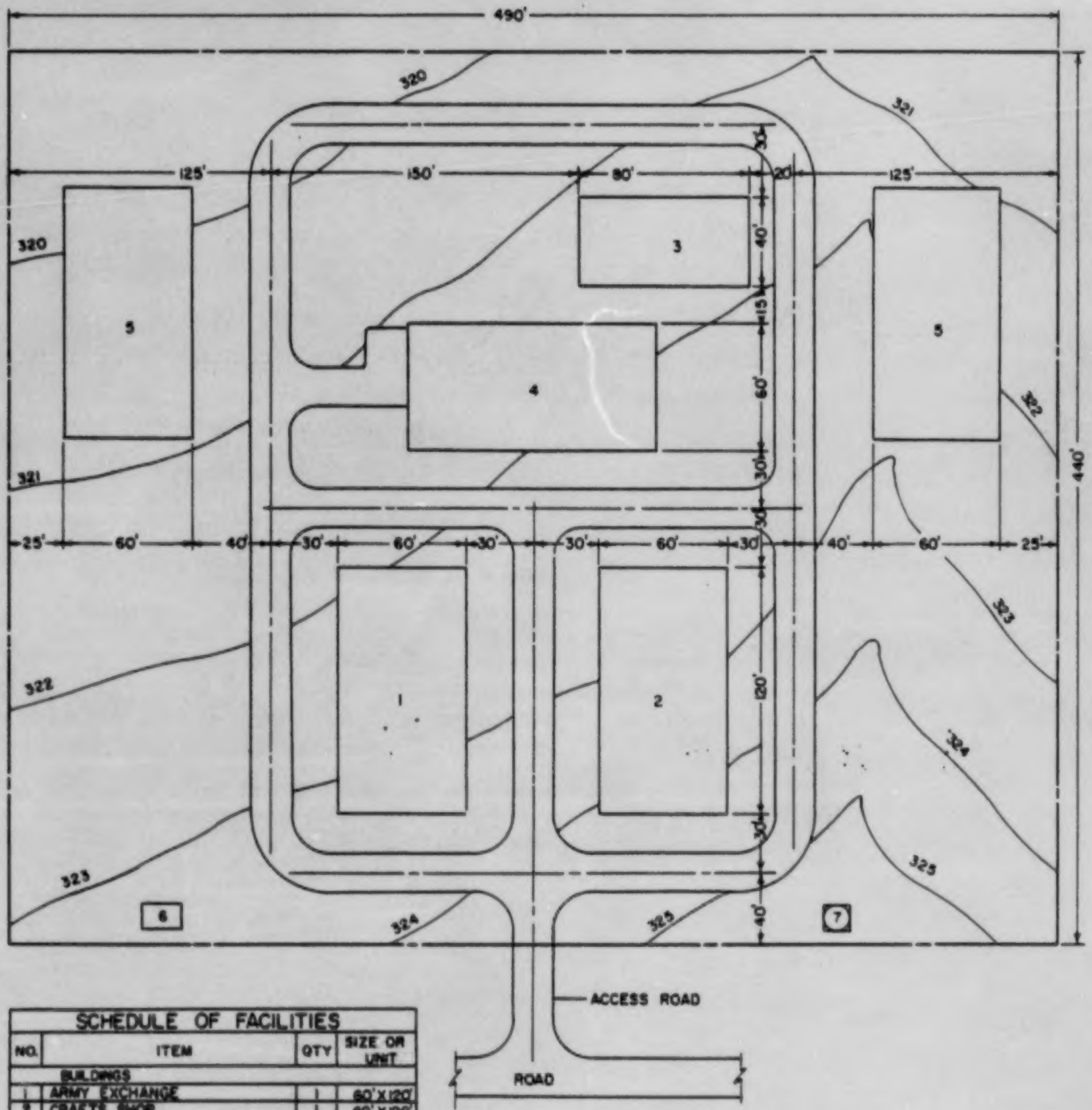
(1) In the case of a building, factors such as overall size, external appearance, arrangement of internal space, and number, size, and kind of doors, windows and fittings are the responsibility of the architect.

(2) The engineer prepares design sketches of the structure based upon calculations concerned with the strength of the supporting members. In addition, the mechanical systems of a building, such as plumbing, lighting, heating, ventilating and air conditioning, are designed by engineers rather than architects.

(3) The architect and engineer together determine the construction materials to be used and methods of work.

b. Construction drawings. Architectural design sketches are used to prepare architectural working drawings. Engineering design sketches are used to prepare engineering drawings. The two are combined to constitute a set of construction drawings. Design is not the draftsman's responsibility. He must, however, understand the construction procedures and their representation well enough to translate design sketches into working drawings.

(1) The views of a structure are presented in general and detail drawings. Detail practices were described in lesson 4. Architectural and structural working drawings, commonly called general drawings, are the assembly working drawings showing plan views and elevation views of the structure.


490'
440'
125'
150'
80'
20'
30'
40'
15'
60'
120'
25'
320
321
322
323
324
325
1
2
3
4
5
6
7
ACCESS ROAD
ROAD

SCHEDULE OF FACILITIES			
NO.	ITEM	QTY	SIZE OR UNIT
	BUILDINGS		
1	ARMY EXCHANGE	1	60'X120'
2	CRAFTS SHOP	1	60'X120'
3	LIBRARY	1	40'X80'
4	RECREATION BUILDING	1	60'X120'
	OTHER CONSTRUCTION		
5	ATHLETIC COURT	2	60'X120'
	ROAD-DOUBLE LANE-6" MACADAM	0.5	MILE
6	SUMP FIRE PROTECTION	1	10,000 GAL
7	WATER TANK	1	10,500 GAL
	SITE AREA	11.2	ACRES

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RECREATION BUILDING-60'X120'
SITE PLAN

Figure 7-1. Site plan.

(2) Plumbing, heating and ventilating, and electrical drawings for small systems normally are shown on one drawing, it being assumed that each trade can identify its installations from the combined plans; or they are sometimes shown on the general plan drawings. For large or complicated installations, separate drawings are made for each utility.

(3) Objects are drawn to scale to show proportions. Distances are never scaled from drawings. All size information must be shown by figured dimensions. Selection of scale is determined by the size of the structure as related to the size of the drawing sheet. A general drawing of a large building, for example, may be prepared at a scale of 1/16″ = 1′-0″ or 1/8″ = 1′-0″; the scale most commonly used is 1/4″ = 1′-0″.

> **Note.** To aid in a better understanding of this lesson, all illustrations pertain to the development of working drawings for a theater of operations 50′ x 92′ recreation building. The general drawings, as illustrated, together with accompanying details (lesson 4) would constitute a set of working drawings for such a building. In studying these drawings notice the manner in which reference is made to all details.

2. PLANS

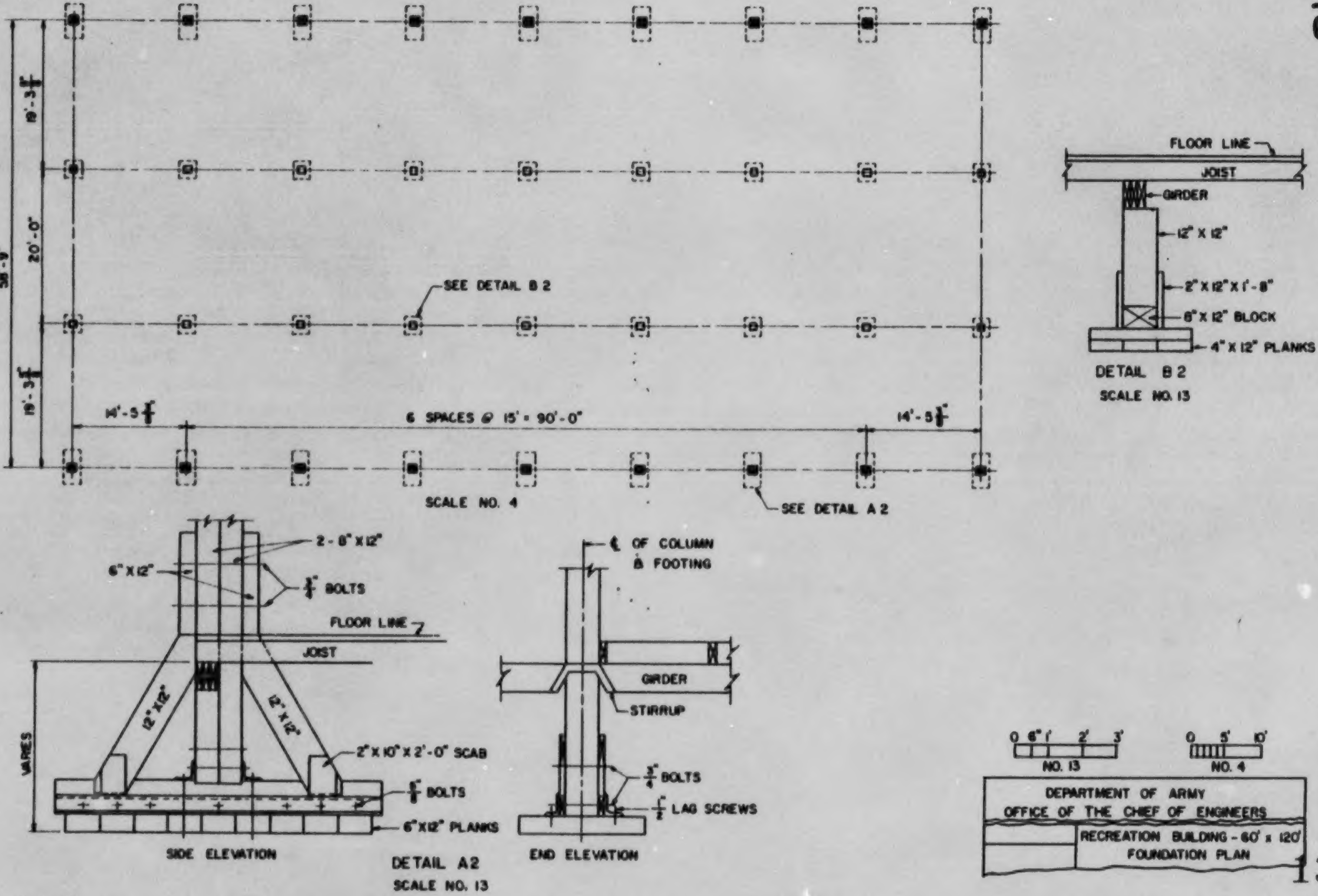
A plan corresponds to a top view, namely, a projection on a horizontal plane. There are several types of plan views which are used for specific purposes, such as site plans, foundation plans, and floor plans.

a. Site plan. A site plan shows the building site with boundaries, contours, existing roads, utilities, and other physical details such as trees and buildings. Figure 7-1 is a typical site plan. Site plans are drawn from notes and sketches based upon a survey. The layout of the structure is superimposed on the contour drawing, and corners of the structure are located by reference to established natural objects or other buildings.

b. Foundation plan. A foundation plan is a top view of the footings or foundation walls, showing their area, and location by distances between centerlines and distances from reference lines or boundary lines. Foundation walls are located by dimensions to their corners, and all openings in foundation walls are shown. Figure 7-2 shows the typical foundation plans for alternate conditions.

c. Floor plan. Floor plans, commonly referred to as plan views, are cross section views of a building. The horizontal cutting plane is passed so that it includes all doors and window openings. A floor plan shows the outside shape of the building; the arrangement, size and shape of rooms; the type of materials; the thickness of walls and partitions; and the type, size and location of doors and windows for each story. A plan also may include details of framework and structure, although these features are usually shown on separate drawings called framing plans.

d. Procedure for drawing plans. Plan views are drawn first because other views depend upon the plan views for details and dimensions. In preparing plan views, a draftsman's job is simplified by following a systematic procedure.


58'-9"
19'-3 3/8"
20'-0"
19'-3 3/8"
14'-5 3/8"
6 SPACES @ 15' = 90'-0"
14'-5 3/8"
SEE DETAIL B 2
SCALE NO. 4
SEE DETAIL A 2
FLOOR LINE
JOIST
GIRDER
12" X 12"
2" X 12" X 1'-8"
6" X 12" BLOCK
4" X 12" PLANKS
DETAIL B 2
SCALE NO. 13
2 - 6" X 12"
6" X 12"
3/4" BOLTS
FLOOR LINE
JOIST
VARIES
12" X 12"
12" X 12"
2" X 10" X 2'-0" SCAB
5/8" BOLTS
6" X 12" PLANKS
SIDE ELEVATION
DETAIL A2
SCALE NO. 13
℄ OF COLUMN & FOOTING
GIRDER
STIRRUP
3/4" BOLTS
1/2" LAG SCREWS
END ELEVATION
0 6" 1' 2' 3'
NO. 13
0 5' 10'
NO. 4
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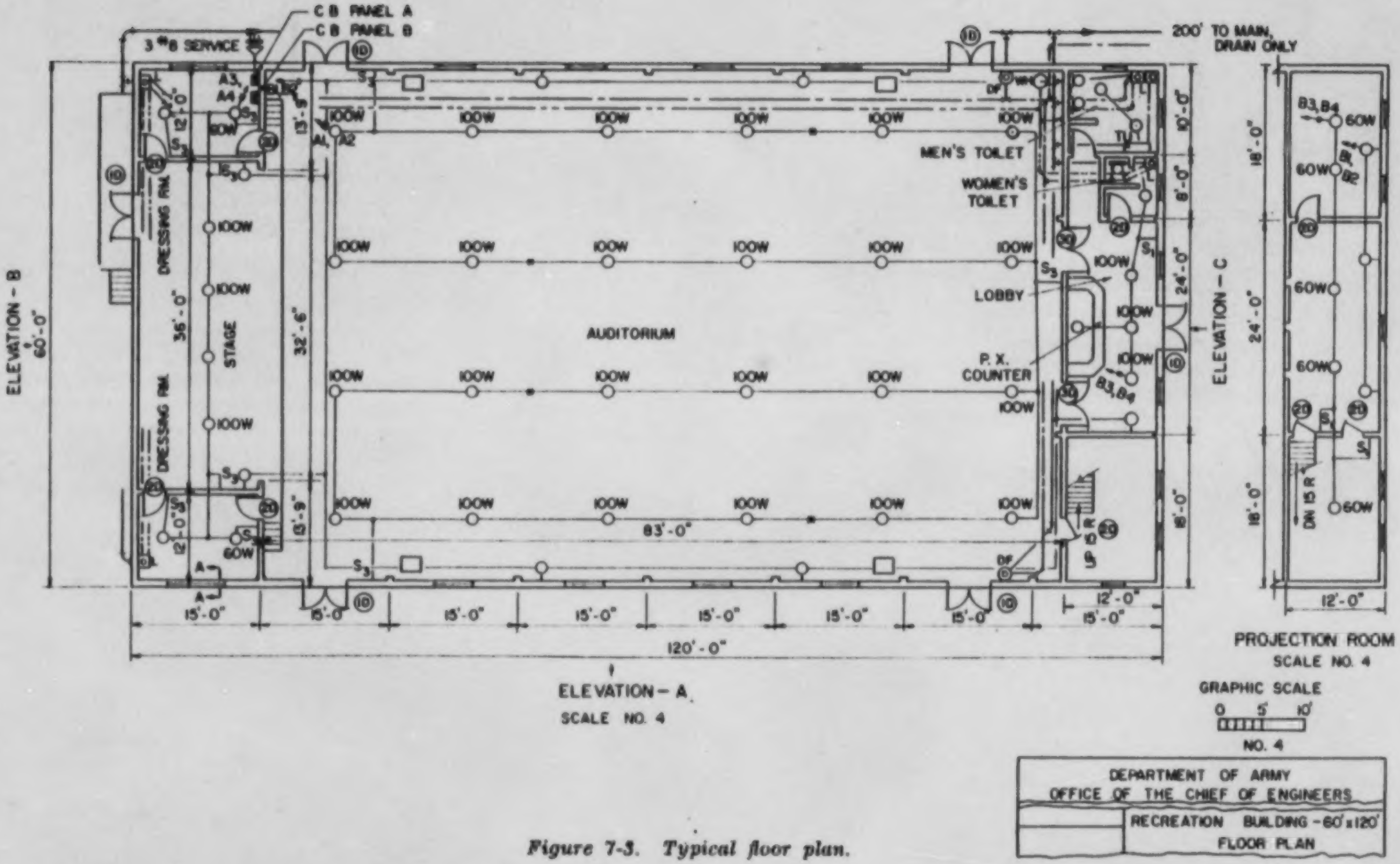
RECREATION BUILDING - 60' x 120'
FOUNDATION PLAN

Figure 7-2. Foundation plan.


C B PANEL A
C B PANEL B
3 #8 SERVICE
200' TO MAIN, DRAIN ONLY
ELEVATION - B
60'-0"
DRESSING RM.
DRESSING RM.
STAGE
36'-0"
32'-6"
13'-9"
13'-9"
AUDITORIUM
100W
60W
MEN'S TOILET
WOMEN'S TOILET
LOBBY
P. X. COUNTER
B3,B4
B1,B2
A1
A2
A3, A4
S3
UP 15 R
DN 15 R
83'-0"
10'-0"
8'-0"
24'-0"
16'-0"
18'-0"
24'-0"
18'-0"
12'-0"
15'-0"
12'-0"
15'-0"
120'-0"
ELEVATION - C
ELEVATION - A
SCALE NO. 4
PROJECTION ROOM
SCALE NO. 4
GRAPHIC SCALE
0 5' 10'
NO. 4
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RECREATION BUILDING - 60' x 120'
FLOOR PLAN

Figure 7-3. Typical floor plan.

(1) **Orientation.** Plan views may be drawn so that the front of the building is at the bottom or right of the sheet. However, when this is not practical, they may be drawn in any arrangement which space permits. Select a suitable scale and lay out the line representing the exterior face of the front wall. Draw the line lightly and allow enough space for notes and dimensions at the bottom or right of the working area. Then, for a symmetrical plan such as figure 7-3, draw the main axis. The main axis corresponds to the centerline of a view and is helpful in centering a plan view.

(2) **Walls and openings.** Proceed from the line representing the exterior face of the front wall. Draw all walls and partitions to scale with light pencil lines. Block out all door and window openings. After all walls, partitions, and openings have been located darken wall and partition lines to a medium line weight.

(3) **Symbols.** After completing wall and partition lines, draw symbols for doors, windows, fixtures, and other details shown in the plan view (fig 4-17 through 4-20).

> Door and window openings are laid out accurately to scale. Door and casement window swings are also drawn to scale; the remaining lines in door and window symbols are spaced by eye.

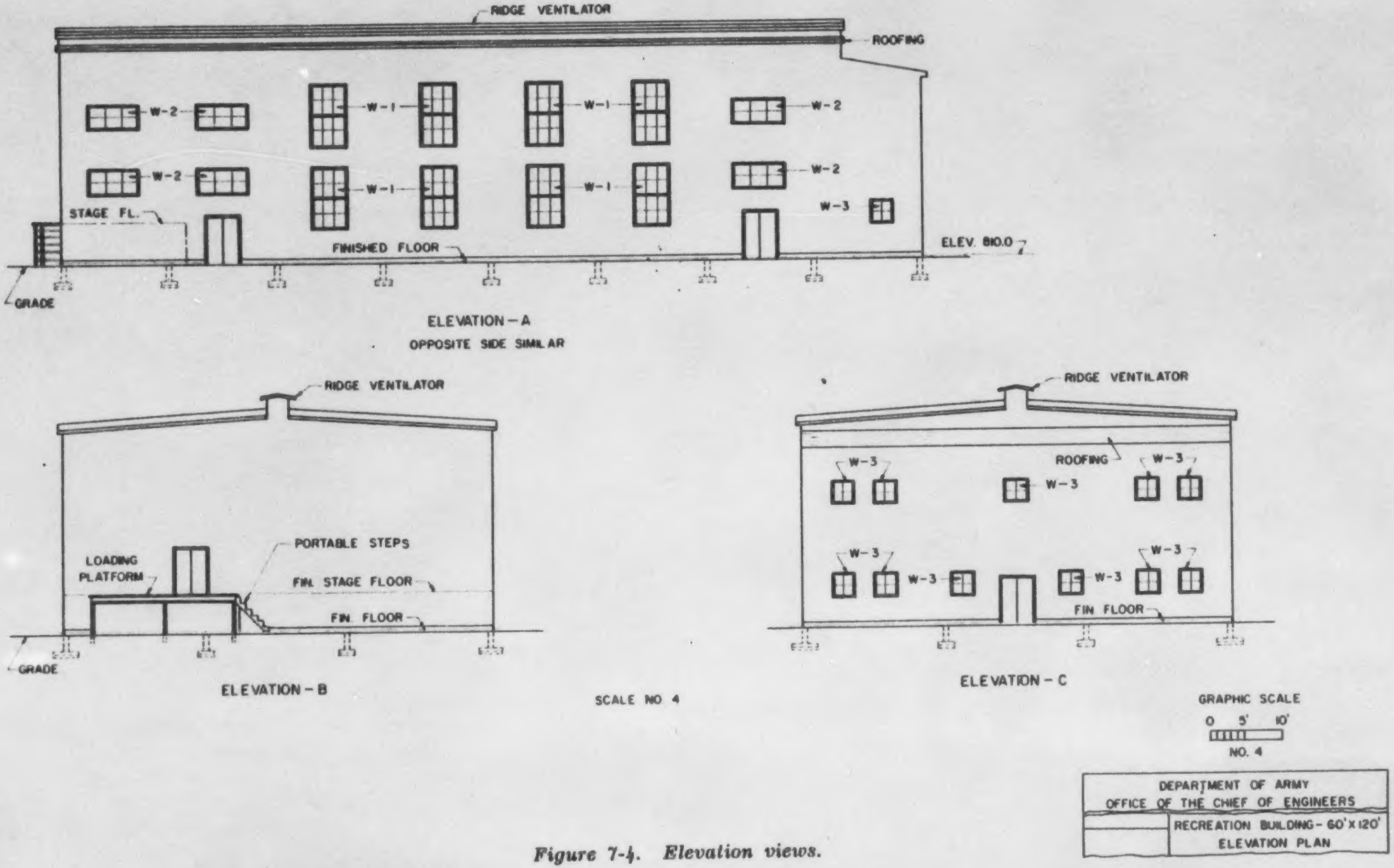
(4) **Number of views.** In most cases, separate drawings are made for each plan view and they will be the only views on the drawing sheet, but, on occasion, may be accompanied by detail or section views. The number of views to be included on a single drawing sheet should be determined by discussion with the men in charge while the drawing is still in the preliminary stage.

(5) **Dimensioning.** Plan views are dimensioned both outside and inside the building lines. Outside dimensions describe changes and openings in the exterior walls in addition to the overall dimensions. Inside measurements locate partitions relative to exterior walls and to each other. All horizontal dimensions are shown on a plan view.

3. ELEVATIONS

Elevations are external views of a structure and may be drawn to show the front, rear, right or left side views. They correspond to the front, rear or side views in orthographic projection because they are projections on vertical planes. An elevation is a picture-like view of a building that shows exterior materials and the height of windows, doors and rooms as in figure 7-4. They also may show the ground level surrounding the structure called the grade. The following procedure is used for developing an elevation:

a. Projection. Complete a related plan view and a typical section before beginning to draw an elevation. These are equivalent to top and side views in machine drawing. The plan and section should be drawn to the same scale decided for the elevation. The section may be placed to one side on the drawing sheet for the elevation. The section


RIDGE VENTILATOR
ROOFING
W-2
W-1
W-1
W-2
W-2
W-1
W-1
W-2
W-3
STAGE FL.
FINISHED FLOOR
ELEV. 810.0
GRADE
ELEVATION — A
OPPOSITE SIDE SIMILAR
RIDGE VENTILATOR
LOADING PLATFORM
PORTABLE STEPS
FIN. STAGE FLOOR
FIN. FLOOR
GRADE
ELEVATION - B
SCALE NO 4
RIDGE VENTILATOR
W-3
ROOFING
W-3
W-3
W-3
W-3
W-3
W-3
W-3
FIN FLOOR
ELEVATION - C
GRAPHIC SCALE
0 5' 10'
NO. 4
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RECREATION BUILDING - 60' X 120'
ELEVATION PLAN

Figure 7-4. Elevation views.

should show the foundation, gradeline, finished floor heights, heights of sills and heads for windows and doors, and the pitch of the roof.

(1) **Vertical dimensions.** Project the gradeline across from the typical section first. Next project the floor and ceiling heights. Use light pencil lines.

(2) **Horizontal dimensions.** Fasten the plan view above the drawing sheet, arranged so that the wall corresponding to the one drawn in elevation is placed nearest to the elevation drawing sheet and parallel to the floor lines. Project lines down from the plan view.

(3) **Procedure.** Work back and forth between the plan and section until exterior details for the elevation in question have been located.

b. **Lines and symbols.** Darken the building outlines and the outlines of doors and windows, and add line and material symbols.

(1) **Line symbols.** Finished floor lines are indicated in an elevation by alternate long and short dashes (same as center line symbol, see fig 7-4) drawn over the other lines. Foundations below grade are shown by the line symbol for hidden details.

(2) **Roof drains.** When used, rain gutters and downspouts are shown in an elevation view.

c. **Notes and dimensions.** Draw guidelines and letter the specific notes identifying building materials. If more than one view is shown on a drawing sheet, identify each view by title. If any view is drawn to a scale different from that shown in the title block, note the scale beneath the view title. No horizontal dimensions are given in an elevation.

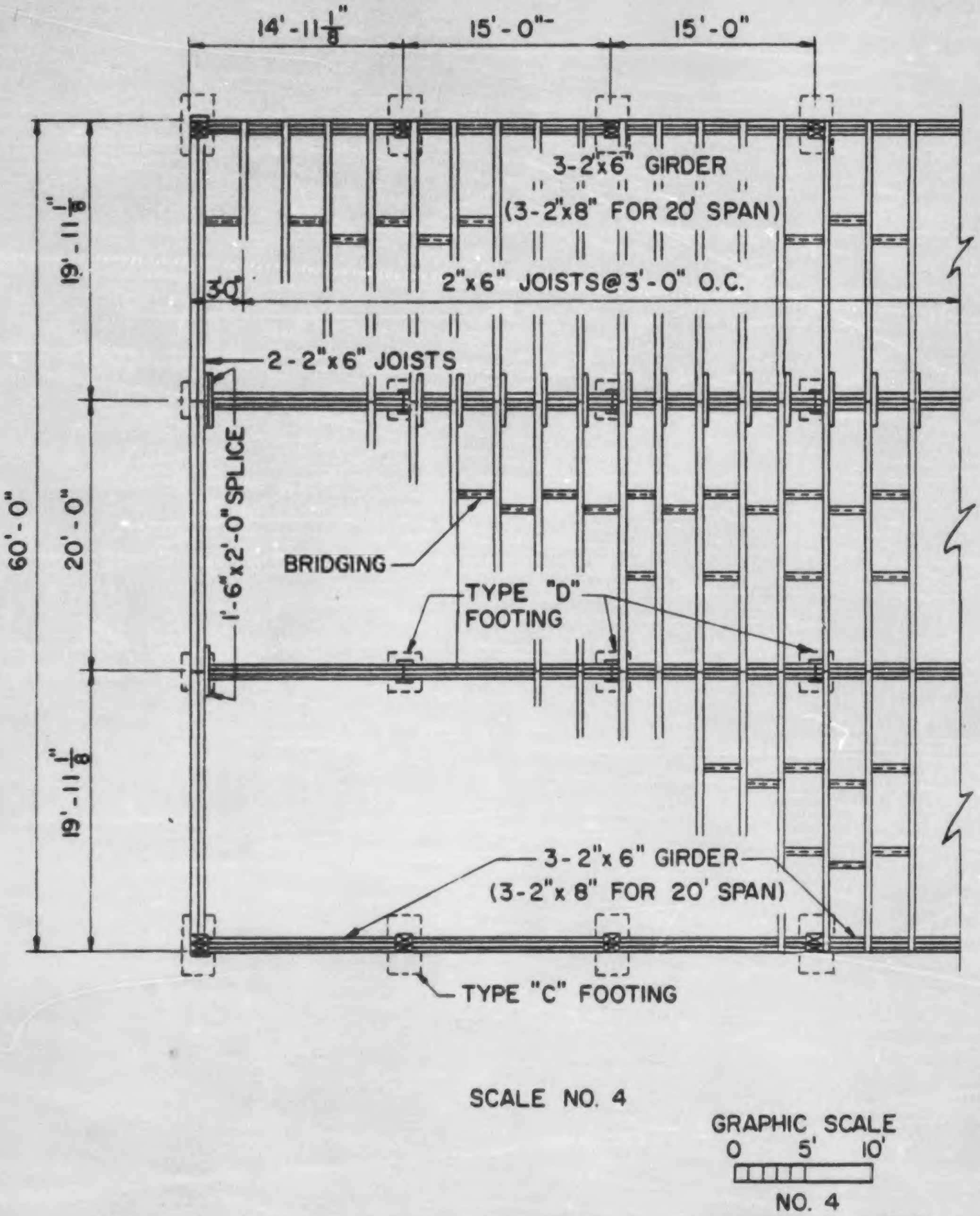
(1) **Elevations.** Finished floor and grade elevations are written as a note, accompanied by a dimension, written on the line symbol denoting the finished floor; the line symbol is extended outside the building area for this purpose. Grade elevations may be given at two points for a sloping gradeline.

(2) **Pane dimensions.** If not included in the window schedule, window pane sizes may be given as fractions in the corners of the windows shown in the elevation; 10/12 written in a corner pane of a multipaned window means that all the panes in that window are 10 x 12 inches in size.

d. **Number of elevations.** The number of elevations drawn for any building is principally determined by the complexity of its shape. A building that is symmetrical about a centerline in the plan view may show adjacent half elevations of the front and rear. Roof, floor, and foundation lines are continuous; a vertical centerline symbol separates the two halves, which are identified by titles centered under each one.

4. FRAMING PLANS

Framing plans show the size, number, and location of the structural members (steel or wood) constituting the building framework. Separate framing plans may be drawn for the floors, walls, and the roof. The floor framing plan must specify the sizes and spacing of joists, girders, and columns used to support the floor. Detail drawings must be added,


14'-11 1/8"
15'-0"
15'-0"
3-2"x6" GIRDER
(3-2"x8" FOR 20' SPAN)
2"x6" JOISTS @ 3'-0" O.C.
3'-0"
2-2"x6" JOISTS
19'-11 1/8"
20'-0"
19'-11 1/8"
60'-0"
1'-6"x2'-0" SPLICE
BRIDGING
TYPE "D" FOOTING
3-2"x 6" GIRDER
(3-2"x 8" FOR 20' SPAN)
TYPE "C" FOOTING
SCALE NO. 4
GRAPHIC SCALE
0
5'
10'
NO. 4

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RECRECATION BUILDING - 60' x 120'
FLOOR FRAMING PLAN

Figure 7-5. Floor framing.

if necessary, to show the methods of anchoring joists and girders to the columns and foundation walls or footings. Wall framing plans show the location and method of framing openings and ceiling heights so that studs and posts can be cut. Roof framing plans show the construction of the rafters used to span the building and support the roof. Size, spacing, roof slope, and all details are shown.

a. Floor framing. Framing plans for floors are basically plan views of the girders and joists. The unbroken double-line symbol is used to indicate joists, which are drawn in the positions they will occupy in the completed building. Double framing around openings and beneath bathroom fixtures is shown where used. Figure 7-5 shows the manner of presenting floor framing plans.

(1) **Bridging** is shown by a double-line symbol with a broken line in the center drawn parallel to the outside lines.

(2) **Notes** identify floor openings, bridging, and girts or plates. Use nominal sizes in specifying lumber.

(3) **Dimensions** need not be given between joists. Such information is given along with notes. For example, 1" x 6" joists @ 2'-0" o.c., indicates that the joists are to be spaced at intervals of 2'-0" from center to center of joists. Lengths are not required in framing plans; the overall building dimensions and the dimensions for each bay or distances between columns or posts provide such data.

b. Wall framing. Wall framing plans are detail drawings showing the location of studs, plates, sills, girts and bracing. (See fig 4-15.) They show one wall at a time and usually are shown as elevation views.

(1) **Door** and **window** framing is shown in wall framing details; openings are indicated by intersecting, single-line diagonals and are identified by the abbreviations D and W.

(2) **Bracing** is indicated by a dashed, double-line symbol and is drawn to scale in its correct location.

(3) **Dimensions.** Vertical dimensions give overall height from the bottom of the sill (for first floor) to the top of the plate or girt. Horizontal dimensions give the spacing of studs on centers.

(4) **Notes.** Specific notes identify types of doors and windows or make reference to general notes. General notes give instructions about such factors as variations in door and window framing, and the installation of bracing.

c. Roof framing. Framing plans for roofs are drawn in the same manner as floor framing plans. A draftsman should visualize himself as looking down on the roof before any of the roofing materials (sheathing) has been added. Rafters are shown in the same manner as joists. (See fig 4-16.)

5. UTILITIES

Plumbing, heating, and electrical systems are the utilities or mechanical systems of a building and are represented by diagrammatic and orthographic drawings. As previously stated, they may be shown on the general plan drawings, be combined on one drawing, or in the case of large installations separate drawings are made for each utility. A draftsman is not

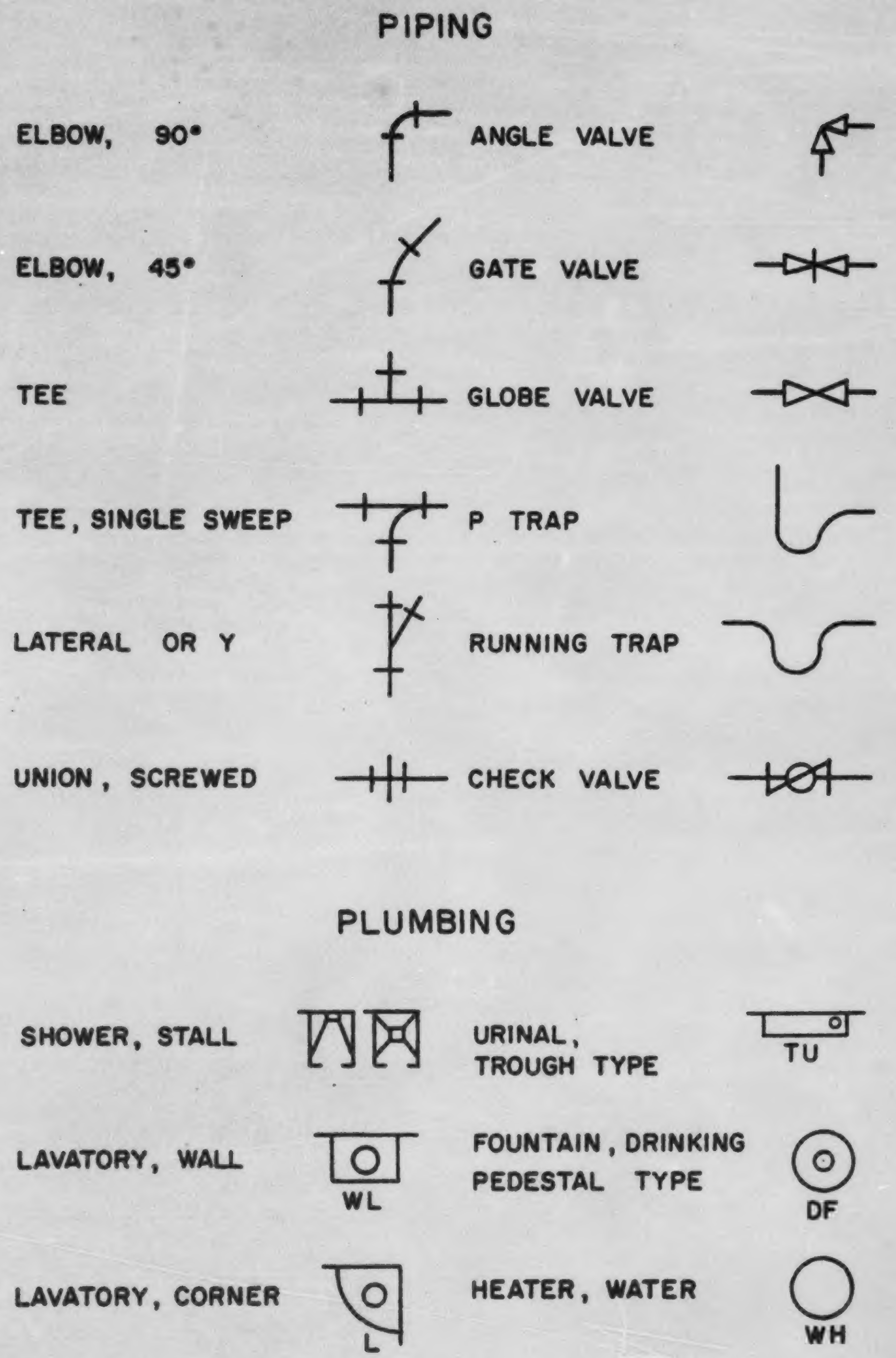

PIPING
ELBOW, 90°
ANGLE VALVE
ELBOW, 45°
GATE VALVE
TEE
GLOBE VALVE
TEE, SINGLE SWEEP
P TRAP
LATERAL OR Y
RUNNING TRAP
UNION, SCREWED
CHECK VALVE
PLUMBING
SHOWER, STALL
URINAL, TROUGH TYPE
TU
LAVATORY, WALL
WL
FOUNTAIN, DRINKING PEDESTAL TYPE
DF
LAVATORY, CORNER
L
HEATER, WATER
WH

Figure 7-6. Plumbing and piping symbols.

required to design these systems but he must be thoroughly familiar with the conventions and symbols used, in addition to the general rules, in order to prepare acceptable drawings from a designer's sketches.

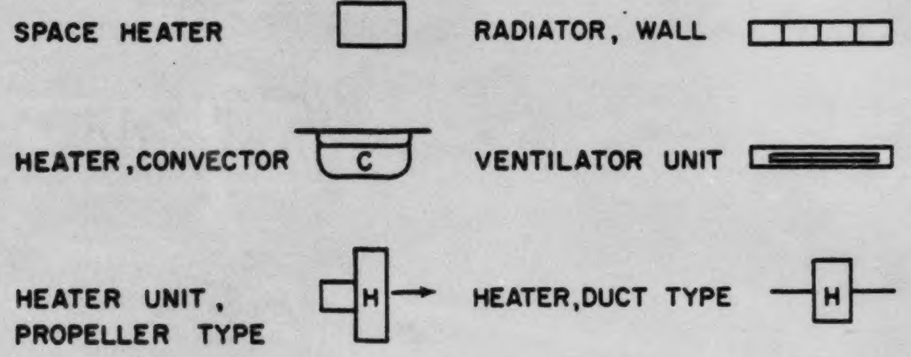

SPACE HEATER
RADIATOR, WALL
HEATER, CONVECTOR
C
VENTILATOR UNIT
HEATER UNIT, PROPELLER TYPE
H
HEATER, DUCT TYPE
H

Figure 7-7. Heating symbols.

a. Symbols. Figures 7-6, 7-7, and 7-8 present the symbols and line conventions most commonly used in preparing utilities plans. Additional symbols for plumbing and heating plans can be found in MIL-STD-17; more symbols for electrical systems in buildings and building distribution systems can be found in MIL-STD-15. The symbols are illustrated as used on drawings of scale 1/8" = 1'-0". When drawings are made smaller than this scale, the symbols may be simplified as long as the basic idea is retained. When drawings are made larger than this scale, the symbols should be presented in greater detail.

b. Drawings. The primary purpose of utility plans is to show the location of piping, heating ducts, wiring and fixtures relative to wall and

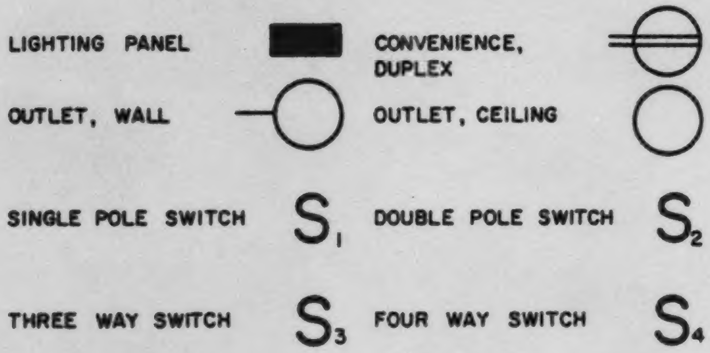

LIGHTING PANEL
CONVENIENCE, DUPLEX
OUTLET, WALL
OUTLET, CEILING
SINGLE POLE SWITCH
S1
DOUBLE POLE SWITCH
S2
THREE WAY SWITCH
S3
FOUR WAY SWITCH
S4

Figure 7-8. Electrical symbols.

partition lines. The complexity of the architectural (general) plan and the installation of utilities determine whether a separate drawing is required; if required, separate plans are prepared by the overlay system. An overlay is begun by fastening a sheet of tracing paper over the general floor plan for which the plumbing, heating or wiring is to be shown; exterior walls and partitions are traced. To prevent confusion, the drawing is kept as simple as possible. Wall thicknesses are shown but no material symbols are used. Door and window openings are shown but door swings are omitted. The following general rules, except as otherwise noted apply in preparing plumbing, heating, and wiring plans whether drawn separately, combined on one drawing or shown on general plans. The plumbing, heating, and wiring plans for the TO building used to illustrate this lesson, are shown on the general plan (fig 7-3).

(1) **Fixtures.** Fixtures are presented symbolically and are drawn in their relative locations. They are the first items to be drawn in the

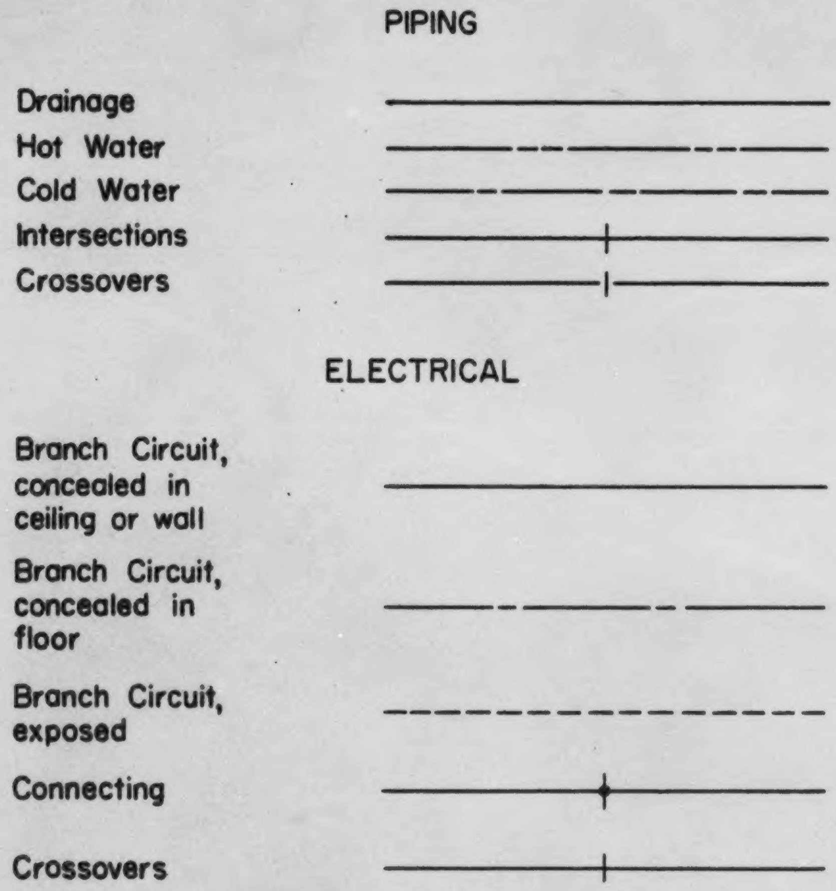

PIPING
Drainage
Hot Water
Cold Water
Intersections
Crossovers
ELECTRICAL
Branch Circuit, concealed in ceiling or wall
Branch Circuit, concealed in floor
Branch Circuit, exposed
Connecting
Crossovers

Figure 7-9. Line symbols.

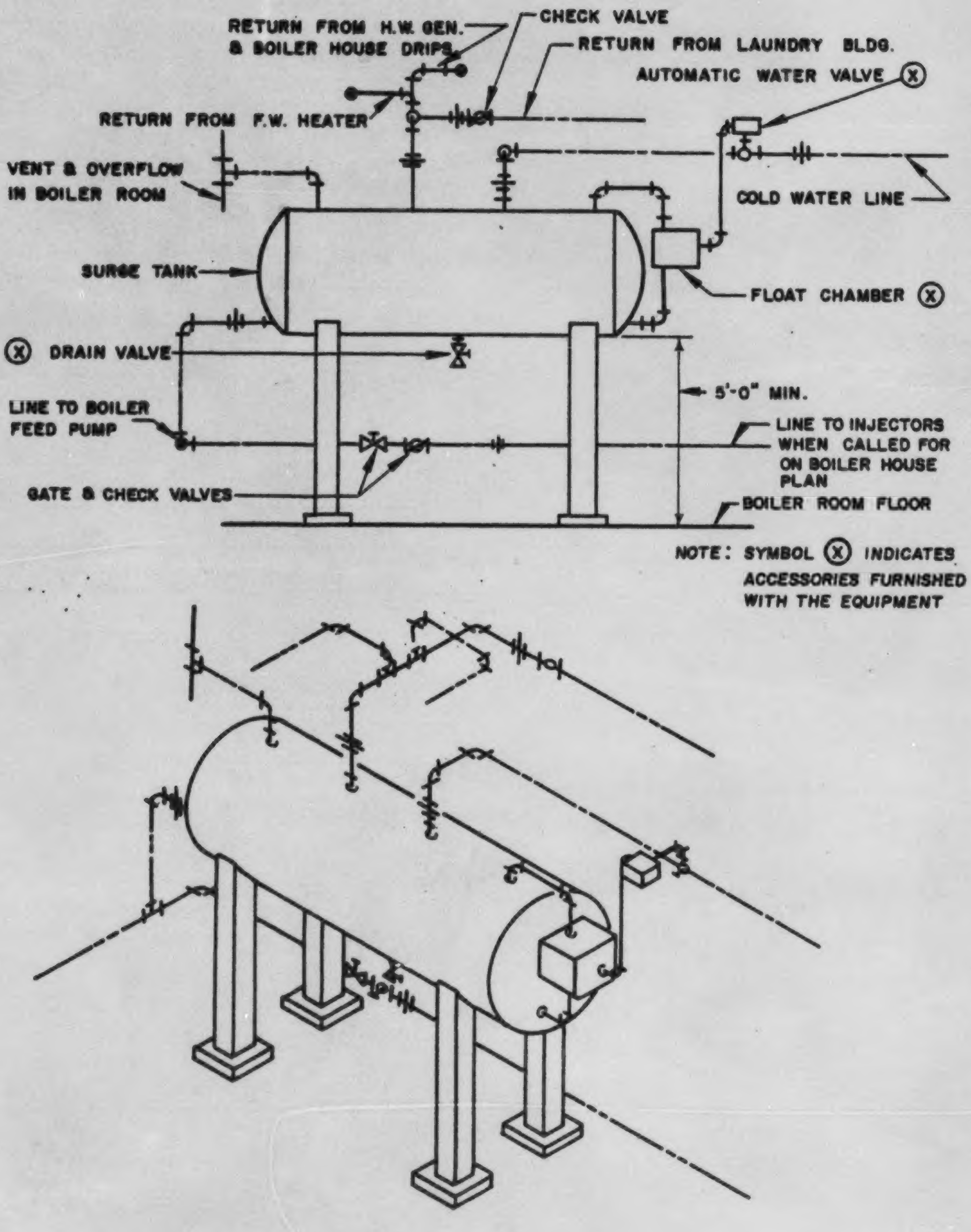

RETURN FROM H.W. GEN.
& BOILER HOUSE DRIPS
CHECK VALVE
RETURN FROM LAUNDRY BLDG.
AUTOMATIC WATER VALVE ⓧ
RETURN FROM F.W. HEATER
VENT & OVERFLOW
IN BOILER ROOM
COLD WATER LINE
SURGE TANK
FLOAT CHAMBER ⓧ
ⓧ DRAIN VALVE
5'-0" MIN.
LINE TO BOILER
FEED PUMP
LINE TO INJECTORS
WHEN CALLED FOR
ON BOILER HOUSE
PLAN
GATE & CHECK VALVES
BOILER ROOM FLOOR
NOTE: SYMBOL ⓧ INDICATES
ACCESSORIES FURNISHED
WITH THE EQUIPMENT

Figure 7-10. Single-line piping, elevation and isometric.

layout after wall and partition lines have been traced. No dimensions are given.

> Note that many symbols are drawn touching the wall line. Corner bath, wall lavatory, low-tank water closet, and electrical wall outlet symbols are examples.
>
> Many symbols must be accompanied by identifying initials when drawn in utility plans. All lettered symbols shown in figures 7-6, 7-7, and 7-8 must be identified in the same way in utility drawings.

(2) **Line symbols.** Pipe for plumbing or heating systems (except warm-air ducts) and wiring diagrams are shown by a single-line symbol. The pipe or wire symbol is drawn between fixtures to give mechanics an idea of the approximate location. The exact length is determined on the job. All runs are identified by nominal size. Figure 7-9 shows some of the common pipe and wire line symbols.

> When fitting symbols are not used on diagrammatic pipe layouts for plumbing plans, the intersection (joining) of any two piping runs is represented by actual contact between lines. Crossovers (no connection between piping) is represented by a break in one of the lines.
>
> Connecting wires are indicated by placing a dot at the point of intersection. No dot is used where wires cross without connecting.

(3) **Vertical views.** Vertical views, such as sections and elevations, are used only to clarify complicated layouts. Finished floor lines and elevations should be shown, and the height of runs should be located from finished floor lines.

> Isometric drawings are the only perspective views used for utility drawings. Figure 7-10 shows an elevation and isometric view for a heating installation. The same drawing principles apply to plumbing and wiring practices.

(4) **Notes and dimensions.** No actual dimensions or dimension lines are shown in utility drawings. Location dimensions and spacing requirements are given in the form of notes or follow installation principles; for example, light fixtures are spaced according to a rule stating that the distance between fixtures is twice the distance between the wall and the first fixture.

c. **Details.** Installation details generally are not required for utility drawings; the systems and fixtures are installed by mechanics according to standard practices for each trade.

6. PRACTICE WORK

Work the exercises which follow to determine just how well you understand the rules and practices for making architectural and structural drawings. Check your answers with the solutions at the back of the booklet. Restudy the attached memorandum where necessary. DO NOT send in your answers to these exercises.

First requirement. Exercise 1 is designed to give you practice in making general drawings.

1. **Plate R** shows the floor plan of a small building. Notice that all electrical and plumbing fixtures are located on the plan. You are required to draw the line-symbols necessary to complete the plumbing and wiring plans. DO NOT submit this practice sheet.

Second requirement. Multiple-choice exercises 2 through 6 will enable you to test your understanding of the rules and conventions as applied to architectural and structural drawings.

2. Which of the following is the responsibility of the architect?
   a. ventilation
   b. wiring diagram
   c. external appearance
   d. construction material

3. Engineering design sketches are used to prepare:
   a. floor plans
   b. framing plans
   c. elevations
   d. window details

4. In making a set of construction drawings which of the following should be drawn first?
   a. front elevation
   b. utility plans
   c. plan views
   d. special details

5. Gutters and downspouts are shown in:
   a. roof framing plans
   b. related plan views
   c. section views
   d. elevation views

6. Utility systems and fixtures are installed in accordance with:
   a. installation details
   b. specific dimensions
   c. standard trade practices
   d. line symbols

Third requirement. The following five exercises are true or false. If you believe a statement is true check "T", if false or only partly true check "F".

7. The construction draftsman translates design sketches into working drawings. T F

8. Plumbing and electrical systems should NOT be shown on general plan views. T F

9. The overall building dimensions and spacing of bays provide data concerning the lengths of joists in framing plans. T F

10. Types of doors are indicated by general notes. T F

11. The drawing of roof framing plans follows the same procedure as that for floor plans. T F

EXERCISES

First requirement. Exercise 1 will enable you to put into practice what you have learned about drawing elevation views. Follow the instructions carefully; your plate will be graded on neatness, layout, correctness of required views, line weights, and accuracy of scale.

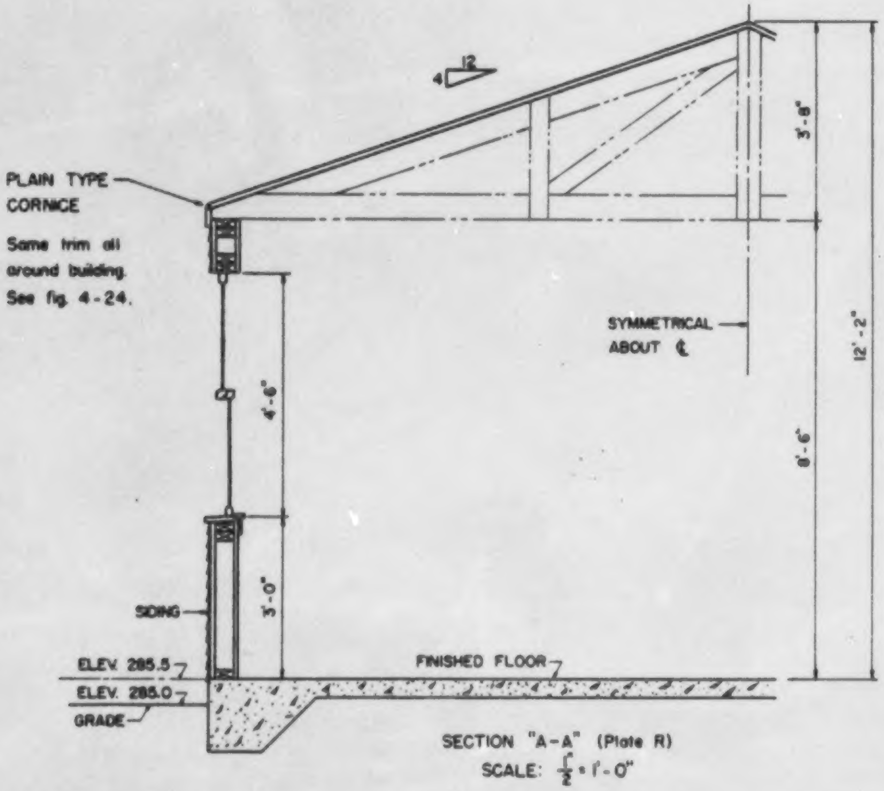

12
4
PLAIN TYPE CORNICE
Same trim all around building. See fig. 4-24.
3'-8"
SYMMETRICAL ABOUT ℄
12'-2"
4'-6"
8'-6"
3'-0"
SIDING
ELEV. 285.5
ELEV. 285.0
GRADE
FINISHED FLOOR
SECTION "A-A" (Plate R)
SCALE: 1/2" = 1'-0"

Figure 7-11. For use with exercise 1.

1.

Figure 7-11 shows a section view of the small building plate R. On plate S, draw elevations A and B (as indicated on plate R) to a scale of ¼" = 1'-0".

Make your drawing similar to figure 7-4 and include the same notes and titles as applicable. DO NOT show footings. Notice that doors and windows are of the same type as in figures 7-3 and 7-4. Construct a graphic scale and place in the lower right-hand corner of the plate.

Second requirement. Solve multiple-choice exercises 2 through 5 to show your understanding of plan views.

2.

Which of the following views in a set of construction drawings is called a plan?

a. top
c. side
b. front
d. back

3.

The site plan is included in a set of working drawings to show:

a. layout of general plans
b. limitations controlling height
c. location of structure in relation to ground area
d. all pertinent zoning regulations

4.

The main axis of a symmetrical plan is the same as a:

a. leader line
c. centerline
b. phantom line
d. break line

5.

Which of the following line weights is used in wall and partition symbols on plan views?

a. thin
c. thick
b. medium
d. extra thick

Third requirement. Multiple-choice exercises 6 through 9 pertain to elevation views.

6.

In a set of construction drawings, which of the following listings are all views called elevations?

a. top, side, and bottom views
c. top, front, and rear views
b. bottom, side, and rear views
d. rear, side, and front views

7.

What is the title of a working drawing which shows the location and dimensions of windows on the right end of a building?

a. right exterior
c. right elevation
b. right auxiliary
d. right projection

8.

Floor and ceiling heights are projected to an elevation view from the:

a. typical section
b. floor plan
c. survey data
d. vertical plane

9.

Which of the following factors influence the number of elevations to be shown for any building?

a. the use for which it is intended
b. its location on the site plan
c. relative orthographic projections
d. the complexity of its shape

Fourth requirement. Solve multiple-choice exercises 10 through 12 to show what you have learned about framing plans.

10.

Joists are shown on floor framing plans by:

a. double-framing symbols
b. reference to framing schedules
c. unbroken double-line symbol
d. approximate location only

11.

Which of the following members in a wood framework construction is a vertical member?

a. sills
b. studs
c. joists
d. rafters

12.

In floor framing plans, which of the following members are represented similar to rafters in roof framing plans?

a. plates
b. girts
c. sills
d. joists

Fifth requirement. Multiple-choice exercises 13 through 16 concern utilities systems.

13.

In preparing utility plans by an overlay of the floor plans:

a. all details shown on the general plan are traced first
b. walls and partitions are shown without symbols
c. window openings and doors swings are included
d. the outline of the building is shown by phantom lines

14.

On a plumbing plan, a single heavy dashed line consisting of 1 long dash and 2 short dashes indicates:

a. waste piping
c. hot water line
b. cold water line
d. changes in pipe size

15.

Dots at the intersection of line symbols for wiring diagrams indicate:

a. circuits are to be connected
c. wires cross without connecting
b. location of fixtures
d. number of wires in a circuit

16.

Heights of runs in vertical views, if used, are located:

a. by specific notes
b. in proportion to fixture heights
c. by general notes
d. from finished floor lines

LESSON 8

MAP DRAWING

CREDIT HOURS ----------3

TEXT ASSIGNMENT ------Attached memorandum.

MATERIALS REQUIRED ----Drafting kit and plate T.

LESSON OBJECTIVE ------To teach you the elementary methods used in map drawing.

SUGGESTIONS ----------Refer to the suggestions made for lesson 1.

ATTACHED MEMORANDUM

1. GENERAL REQUIREMENTS

In numerous cases the engineering draftsman must either be capable of drawing maps of small areas or of understanding and interpreting them. In the previous lessons in engineering drawing the three dimensions of an object were represented by two or more views or in one isometric drawing. In drawing maps, the heights and depths of the earth's natural features must be indicated by symbols (par 5) used on a single view. Maps may be classified according to the type of information, size of scale, or their intended use.

a. **Type of information.** When classified according to type of information, maps fall into three general types as follows:

Real information. Maps of this type show highways, lakes, rivers or other natural features in their actual location and to a scale which indicates their relative sizes.

Imaginary information. Maps of this type show political subdivision for example, state, county, township or personal property lines.

Relief maps. Maps of this type show heights and depths of the area by contour lines or curves through points of equal altitude.

b. **Size of scale.** When classified according to scale, maps fall into three general categories as follows:

Large scale—1:75,000 or larger

Medium scale—between 1:75,000 and 1:600,000

Small scale—1:600,000 or smaller

c. **Intended use.** Maps are used for many purposes, and the following list includes a few of those of particular interest to the engineering draftsman.

Topographic maps are large scale geographic maps which show the relationship of natural features to man built features. The relief is generally represented by contour lines.

Engineering maps are site maps giving the location and construction requirements for engineering projects. Such maps show area contours, objects which must be removed before construction begins, objects which must remain and objects which may present interference problems.

Military maps show essential information of a military nature within the area.

2. GRAPHIC SCALES

The scale of a map is the ratio of a measurement between two points on the map to the corresponding true measurement between the same two points on the ground. This ratio is always written with the map distance as 1, thus for all consistent units of measurement:

$$\text{map scale (MS)} = \frac{\text{map distance (MD)}}{\text{ground distance (GD)}} \text{ or } \frac{1}{\text{GD}}$$

On most military maps ground distance is measured by means of a graphic scale. A graphic scale is a bar scale or ruled scale printed on the map and marked so that true distances may be found by measuring map distance with the graphic scale. Most maps have three or more graphic scales, in different units of measurement: miles, meters, yards, feet, and so on. The portion to the right of zero is marked in full units of measurement and is called the primary scale. The portion to the left of zero is subdivided into tenths of a unit and is called the extension scale. In order to construct a graphic scale, two values must be known: (1) the map scale and (2) the ground distance which the scale is to represent.

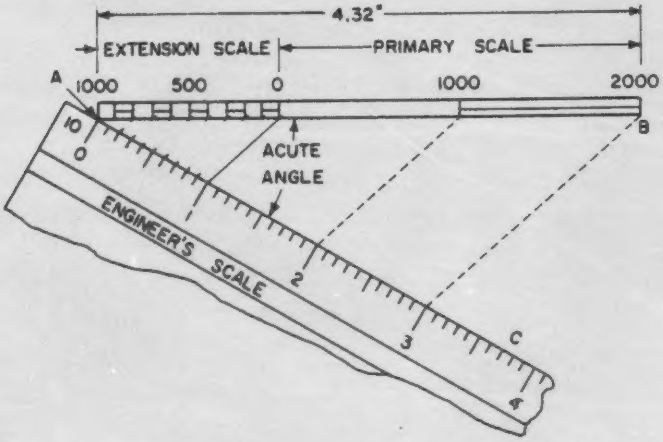


Figure 8-1. Constructing a graphic scale.

Example: Construct a graphic scale to represent 3000 yards actual ground distance on a map of scale 1:25,000.

Solution:

$$MD = 3000 \times \frac{1}{25000} = 0.12 \text{ yards}$$

$$0.12 \text{ yds} = 0.12 \times 36 = 4.32 \text{ inches}$$

The following steps in construction are illustrated in figure 8-1.

Step 1. Draw a line AB, of length 4.32 inches and make bar AB about ⅛ inch wide.

Step 2. Draw line AC at a convenient acute angle from AB.

Step 3. Using engineer scale, mark off three equal distances along AC, shown in figure 8-1 as 1, 2, and 3. Mark off 10 equal subdivisions from 0 to 1 on line AC.

Step 4. Draw line from point 3 to point B, and transfer all points marked on AC to line AB by construction lines parallel to line 3B.

Step 5. Complete graphic scale by drawing divisions and subdivisions of bar AB at points transferred from AC. The subdivisions of the extension scale are marked from 0 to 1000 to the left. The primary scale is marked from 0 to 2000 to the right. The horizontal line through every other section of the scale is for clarity in reading.

3. RELIEF DRAWING

A complete topographic drawing shows not only the property lines and the relative position of geographical features but some indication of elevations and depressions of the area.

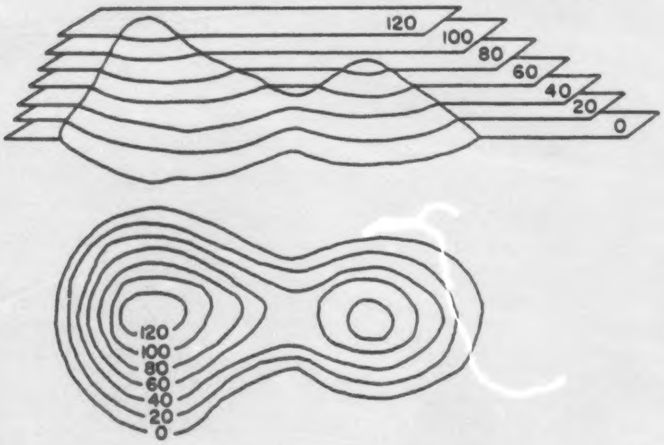


Figure 8-2. Contour lines.

a. The most commonly used method of showing relief is the contour line method. The contour line method is based upon the principle of a series of equally spaced horizontal planes cutting through the vertical features of the earths surface. A line drawn connecting all the points where the horizontal plane actually cuts the vertical feature will result in a series of curves called contour lines.

b. Figure 8-2 shows two hills cut by a series of horizontal planes marked by their altitude in feet above the level or base plane as 0, 20, 40, 60, 80, 100, 120. The intersections of the planes with the sides of the hills are drawn in elevation in the upper half of the figure and the irregular contour lines thus formed are shown in the lower half as they would appear on the relief drawing. Note that contour lines are marked 0, 20, 40, 60, 80, 100, and 120 to show the elevation (in feet) of all points on the line. The disadvantage of contour lines is that they present such a complicated pattern that they often obscure other significant terrain features.

c. There are several methods of indicating relief features but the contoured map has replaced all other types for military use.

4. LOGICAL CONTOURING

a. **Contour characteristics.** A careful study of relief maps reveals that the contour lines themselves possess several important characteristics as follows:

(1) Contours are smooth curves.

(2) Contours never cross or touch except at overhanging or vertical cliffs and at waterfalls.

(3) Contours are approximately V-shaped in narrow valleys, with the V pointing upstream; are generally shaped as U's pointing down ridges, and are shaped as an M just above stream junctions.

(4) Contours tend to parallel streams and to parallel each other. This reflects the fact that changes in ground form are usually gradual.

(5) Contours never fork.

(6) Every contour closes on itself, either within or outside the limits of the map.

(7) Contours are spaced equally along a uniform slope. It is possible to sketch the contours on a map with considerable accuracy, by applying these characteristics to the field notes submitted by the surveyor. The procedure for sketching contours in this manner is called **logical contouring.** The surveyor usually furnishes spot elevations at all points where there is a change in slope (fig 8-3) and the elevations of intermediate points are determined by interpolation.

> **Note.** The surveyors notes taken in the field are recorded on a field sheet called a plane table sheet.

b. **Procedure.** Logical contouring should be approached systematically, and for best results may be divided into the following five steps:

Step 1. Determine the elevation of all stream junctions.

Step 2. Locate the points where contours cross the streams.

Step 3. Sketch in the ridgelines.

Step 4. Locate the points where contours cross the ridges.

Step 5. Draw the contours by connecting points of equal elevation.

c. Illustration. In the illustrative problem which follows, the procedure above is used to sketch contours at 20 foot intervals to the map shown in figure 8-3. The map contains a drainage pattern and some spot elevations furnished by the surveyor.

(1) The first step is to determine the elevations of all the stream junctions.

With a pair of dividers, stream junction "A" is determined to be ¼ of the distance from the known elevation 30 to the known elevation 110 (fig 8-3). Since the total difference in elevation is 80 feet, ¼ of that is 20 feet. Stream junction "A" is therefore 20 feet higher than stream junction 30 and is at an elevation of 50 feet.

Similarly, stream junction "B" is determined to be 5/6 of the way from stream junction 30 to point 102, or at elevation 90 feet.

These elevations are added to the map, as in figure 8-4.

(2) The second step is to locate the points where contours cross the streams (fig 8-5).

The lowest elevation on the sheet is 10 feet and is located in the lower right-hand corner where the main stream crosses the edge of the sheet. Since contours are being plotted at 20-foot intervals, the lowest contour on the sheet will be the 20-foot contour. Along the stream the 10- and 30-foot elevations are shown. Since the slope of the stream is assumed to be constant, the 20-foot elevation may be located halfway between the 10- and 30-foot elevations. This division is made with a pair of dividers by trial and error.

In indicating the points where the contours cross the streams, use the characteristic V-shaped mark. (See par **a**(1), above.)

The next given spot elevation on the main stream above the 30-foot stream junction is the 110-foot elevation. (While it is true that the elevation of stream junction 50 has already been computed, it is best to work from the measurement made in the field.) The next 20-foot contour above the 30-foot elevation will be at 40 feet, a difference of 10 feet. The total difference in elevation between the known points is 110 minus 30, or 80 feet. The distance from 30 to 40 is therefore 10/80 or ⅛ of the total.

By using a pair of dividers, the distance between known elevations 30 and 110 is divided into eight equal parts, each representing 10 feet difference in elevation. The first division above the 30-foot elevation is 40 and is marked by the characteristic V-shaped contour crossing. Two more divisions locate the 60-foot

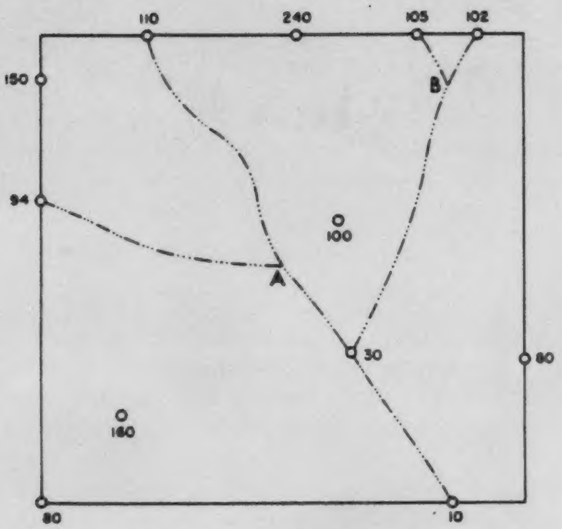

110
240
105
102
150
B
94
100
A
30
80
160
80
10

Figure 8-3. Logical contouring—plane table sheet.

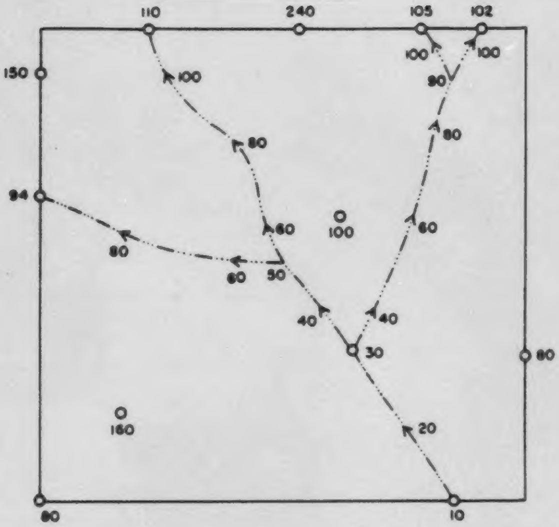

110
240
105
102
100
100
150
100
90
80
80
94
60
100
60
80
60
50
40
40
30
80
20
160
80
10

Figure 8-5. Logical contouring—locating points where contours cross streams.

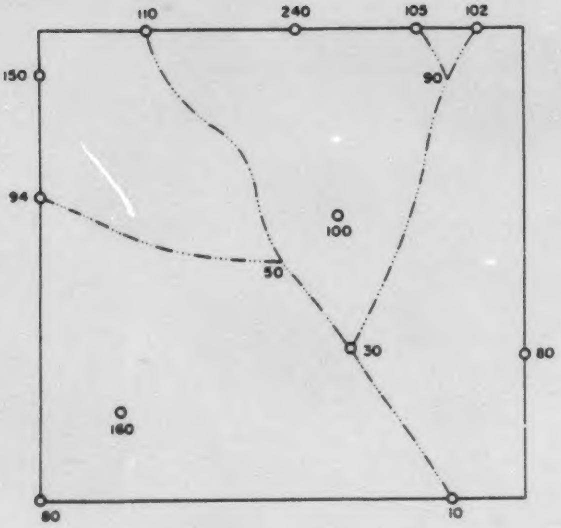

110
240
105
102
150
90
94
100
50
30
80
160
80
10

Figure 8-4. Logical contouring—elevation of stream junctions.

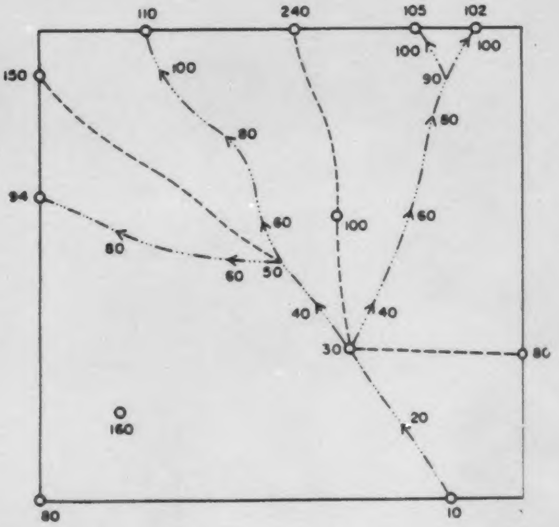

110
240
105
102
100
100
150
100
90
80
80
94
60
100
60
80
60
50
40
40
30
80
20
160
80
10

Figure 8-6. Logical contouring—sketching ridgelines between streams.

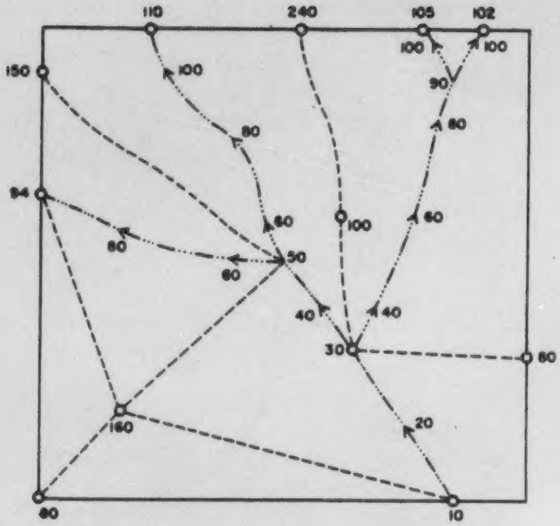

110
240
105
102
150
94
100
90
80
60
50
100
40
30
80
160
20
80
10

Figure 8-7. Logical contouring—sketching ridgelines to spot elevations.

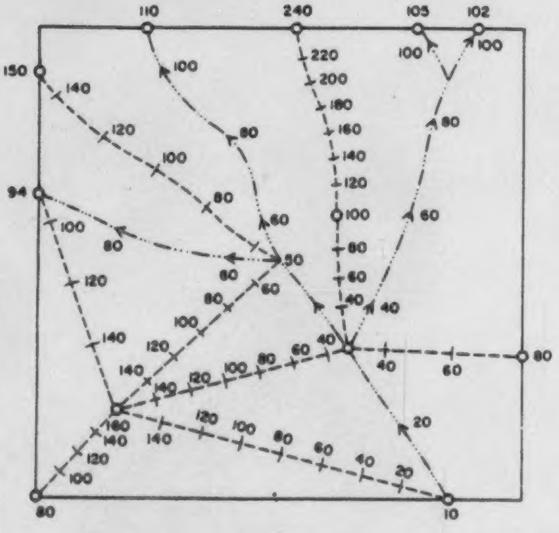

110
240
105
102
150
94
220
200
180
160
140
120
100
80
60
50
40
30
80
160
20
80
10

Figure 8-8. Logical contouring—locating points where contours cross ridges.

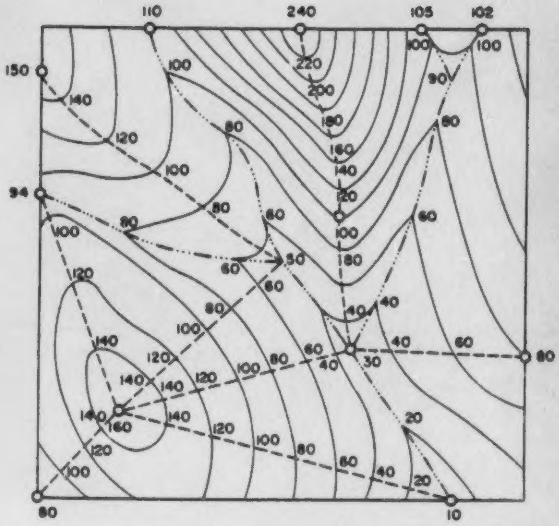

110
240
105
102
150
94
220
200
180
160
140
120
100
90
80
60
50
40
30
80
160
20
80
10

Figure 8-9. Logical contouring—drawing contours.

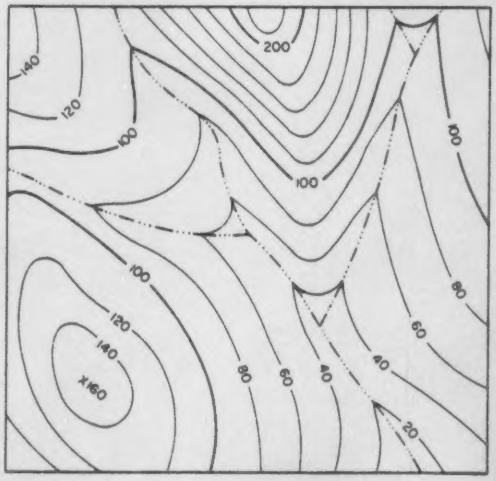

200
140
120
100
100
100
100
120
140
x160
80
60
40
80
60
40
20

Figure 8-10. Logical contouring—indexing.

contour. The 80- and 100-foot elevations are located in a similar manner.

The difference in elevation between 30 and 102 is 72 feet. The 40-foot contour will be placed 10/72 of the total distance above 30. Since 10/72 is about 1/7 of the distance, the space is divided into 7 equal parts with the dividers and the 40-foot elevation marked. The 60, 80, and 100-foot elevations are marked on every second space as for the main stream, above.

All other intersections of contour lines and streams are similarly determined.

(3) The third step is to sketch in the ridgelines.

Streams are always separated by higher ground between them. If there were no higher ground to separate the streams, they would flow together, forming a swamp or lake (fig 8-6).

A ridgeline will, therefore, run between two streams and down into the stream junctions.

In plotting ridgelines remember that the surveyor gives spot elevations where there is a change in slope. The crest of a ridge is one place where slope changes, and spot elevations falling between streams may therefore be assumed to lie on the crest of the ridge.

Bearing these two facts in mind, one may sketch the ridges by running lines through the spot elevations which fall between streams and down into the stream junctions, curving the lines where necessary to keep them roughly midway between the streams as shown by the dashed lines of figure 8-6.

Note. Additional lines may be drawn between the spot elevations falling between streams and other points of known elevation as shown by the lines radiating from the spot elevation 160 in figure 8-7. Take care, however, that these lines do not cross either each other or a stream.

(4) The points where contours cross the ridges (fourth step) are determined in the same way as the locations where contours cross the streams.

Taking as an example the ridge which runs from stream junction 50 to spot elevation 150 (upper left-hand corner, fig 8-7), the total difference in elevation is 100 feet.

The 60-foot contour will cross the ridge 10/100 or 1/10 of the way up from the 50-foot stream junction.

The 140-foot contour crosses the ridge 1/10 of the way down from the 150-foot elevation.

The remaining 80 feet are divided into four equal parts to locate the 80-, 100-, and 120-foot contours.

Contours crossing a ridge are U-shaped with the curve of the U pointing downhill.

The points where contours cross the other ridgelines are plotted in a similar manner (fig 8-8).

(5) Since by definition a contour is a line connecting points of equal elevation, all that is necessary to draw the contours (fifth step) is to connect the points previously plotted.

In drawing the contours one must guard against the tendency to connect points with straight lines, but instead draw the contours as smooth curves which follow the shape of the drains as far as possible.

The method of drawing contour lines is shown in figure 8-9.

Index contours are accentuated (in the case of this problem, the 100-foot and 200-foot elevations), guide lines and unnecessary elevations removed, and contour lines numbered, as in figure 8-10. The job is then complete.

From only a drainage pattern and some scattered spot elevations there has been developed a contoured sheet on which the elevation of any point may be readily determined.

5. TOPOGRAPHIC SYMBOLS

The various symbols used on a map, when possible, resemble the features they represent. Most of the symbols used in topographic drawing may be grouped under the following headings:

Water and drainage features (printed in blue).

Relief, or contours (printed in brown).

Vegetation (printed in green).

Cultural, or man-made works (printed in black).

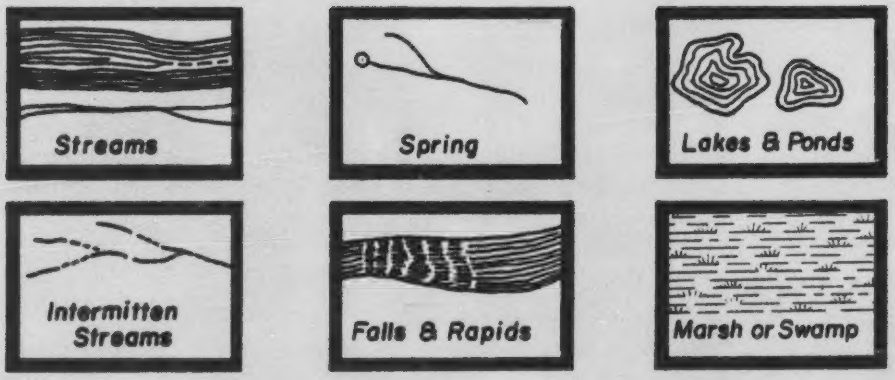


Figure 8-11. Symbols for water and drainage features.

Figures 8-11, 8-12, and 8-13 illustrate a few of the symbols used for water, vegetation, and culture respectively. The method of representing relief was covered above. No suggestion is needed as to the method of their execution, and no attempt is made herein to include all the symbols which might appear on a map. Anyone familiar with the use of road maps will recognize many of the symbols given and their use. A legend on the map usually explains the symbols used thereon.

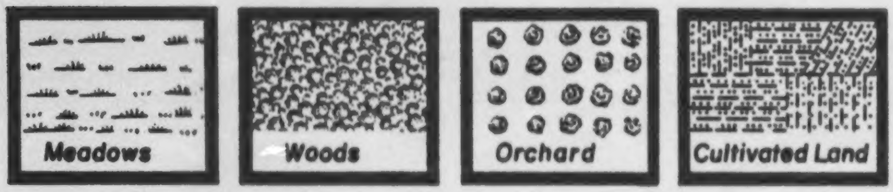

Meadows
Woods
Orchard
Cultivated Land

Figure 8-12. Symbols for vegetation features.

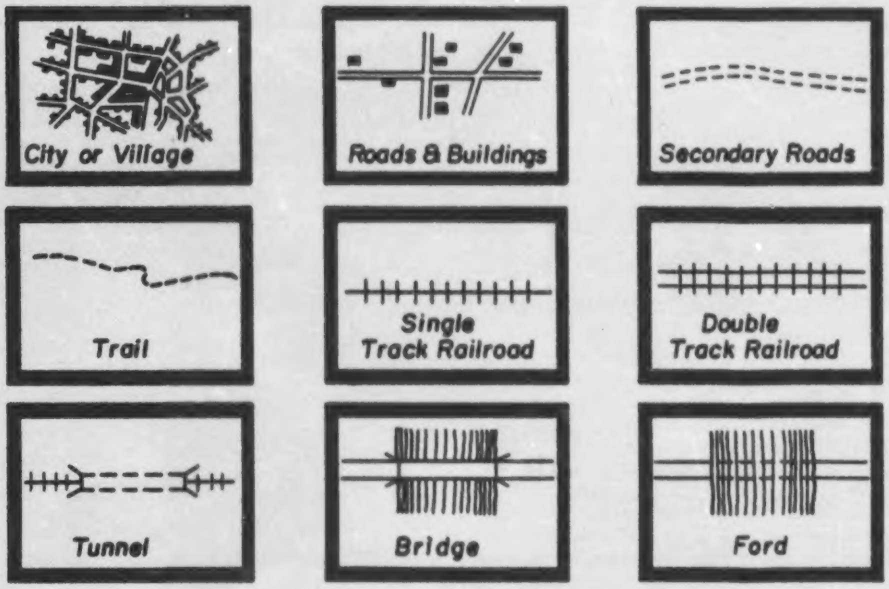

City or Village
Roads & Buildings
Secondary Roads
Trail
Single Track Railroad
Double Track Railroad
Tunnel
Bridge
Ford

Figure 8-13. Symbols for cultural features.

6. PRACTICE WORK

Work the true or false exercises which follow to determine just how well you understand the practices used in drawing maps. Check your answers with the solutions at the back of the booklet. Restudy the attached memorandum where necessary. DO NOT send in your answers to these exercises.

1. Some types of maps, like isometric drawings, show three dimensions on a single flat piece of paper. T F

2. When classified according to type of information a map may show information that is true or imaginary. T F

3. If map A is drawn to scale 1:1,000,000 it is considered to be a very large scale map. T F

4. Topographic maps show information by topics as shown in the title block. T F

5. The third dimension is shown on relief maps by the use of contour lines. T F

6. Most maps have three or more graphic scales in different units of measurement. T F

7. A line drawn on a map to show a state line is an example of real information. T F

8. In the scale ratios of maps, the larger the denominator the smaller the scale. T F

9. The symbols used on maps are drawn true to scale of the map. T F

10. The most widely used method of showing heights and depths on a map is by use of contour lines. T F

EXERCISES

First requirement. Exercise 1 is intended to give you an opportunity to demonstrate your ability to apply logical contouring in the plotting of relief features on a map. Follow the instructions carefully; your work will be graded on neatness, completeness, and accuracy.

1.

Plate T is a surveyor's plane table sheet showing the drainage pattern of an area. The requirement is to complete this sheet to show the contour lines at 10-foot intervals. Observe the following:

Use logical contouring method (steps 1 through 5, paragraph 4b).

Determine and record elevations at stream junctions A, B, C, and D (use HB pencil to record elevations).

Use 4H pencil to sketch ridgelines between streams.

Use 2H pencil to mark the V's and U's where 10-foot contours cross streams and ridgelines. The elevation numbers should be marked lightly to allow easy erasure and relocation of numbers if desirable.

Use 2H pencil to complete (connect) all contour lines and HB pencil to letter the elevations at 10-foot intervals.

Retrace the 250-foot and 300-foot contours with HB pencil so that they will stand out as index contours, similar to the 100-foot contour in figure 8-10.

Second requirement. Solve multiple-choice exercises 2 through 11 to show that you understand the elements of topographical drawing.

2.

In drawing military maps the heights and depths of the area are indicated by:

a. use of isometric plotting paper

b. symbols on a single view

c. drawing a side elevation

d. Arabic numbers in margin

3.

A military map is a map which shows information:

a. of no use to the general public

b. not required by the naval forces

c. of military nature in the area

d. which is classified as confidential or secret

4.

The scale given on a map is the ratio of

a. a map distance to the corresponding ground distance

b. a ground distance divided by the corresponding map distance

c. the map area to the corresponding ground area

d. the ground area to the corresponding map area

5.

How many scales are used to construct a map?

a. one only

b. two only

c. three only

d. three or more

6.

How many graphic scales are usually shown on a map?

a. one only

b. two only

c. three only

d. three or more

7.

A relief drawing is a topographic drawing of an area which shows natural features, and in addition

a. the different scales used in constructing it

b. all man made features

c. the location of proposed public works

d. some indication of heights and depressions

8.

Logical contouring is a method of drawing contours on maps:

a. without making field survey, by estimating by eye

b. from surveyors field data sheets and spot elevations where slope changes

c. by use of pure logic that water flows downstream

d. by passing imaginary planes from stream junctions to high points where slope changes.

9.

The symbols used on maps are drawn:

a. to exact size for accuracy in measurement

b. with all symbols reading from bottom or right side

c. to an exaggerated size for legibility

d. to the scale shown in the legend

10.

To obtain the best results in logical contouring is should be:

a. done in 5 steps beginning with highest spot elevation

b. approached systematically in a sequence of five steps

c. done in the field where it can be checked for errors

d. done by use of (special) drafting instruments

11.

Which one of the following statements is not a true characteristic of contours?

a. contours never fork

b. contours are smooth curves

c. all contours are closed curves

d. contours crossing streams are V shaped pointed down stream

LESSON 9

DRAWING REPRODUCTION

CREDIT HOURS __________2

TEXT ASSIGNMENT ______Attached memorandum.

MATERIALS REQUIRED ____None.

LESSON OBJECTIVE ______To acquaint you with the commonly used methods for reproduction of drawings, and to point up the importance of good draftsmanship to procure good reproductions.

SUGGESTIONS ___________Refer to the suggestions made for lesson 1.

ATTACHED MEMORANDUM

1. REQUIREMENT FOR REPRODUCTION

A drawing when completed represents too much time and effort to be treated casually. It is a valuable record, and must be preserved with care. If an original drawing were to be used on the job and passed from man to man, it would soon become worn and too dirty to read. For this reason, working drawings used on a job are almost always reproductions of original drawings prepared in the drafting room. The original may be either a pencil or an ink drawing made on translucent tracing paper or tracing cloth.

> In this study of engineering drawing you have worked with pencil on drawing paper only. However, you have progressed through the essential steps of preparing working drawings. Drafting requirements are basically the same whether you are required to produce pencil lines or inked lines on tracing paper or tracing cloth. Pencil or ink lineweights should be **sharp, opaque,** and **uniform** to produce a clear, sharp reproduction of the original drawing.

2. REPRODUCTION PROCESSES

There are a number of different processes for reproducing drawings, all of which give best results from inked tracings. However, pencil drawings on tracing paper give satisfactory results when the penciling is done skillfully. In fact, very few drawings are inked; only those of a permanent nature such as those required for map reproduction, charts, and so on, are inked. The various methods of duplication may be divided into three categories: contact, photo, and copy. The method to be used depends on a number of factors. One factor, of course, is the type of duplicating equipment available; another is the relative cost of the various processes; and a third is the use to which the duplicate will be put. The most widely used reproduction processes are described briefly.

3. CONTACT PRINTS

All contact printing processes involve photochemical processes of one type or another. The paper upon which the drawing is to be printed is coated or sensitized with a chemical preparation affected by the action of light. When such paper is exposed to light in a printing frame, or machine, with the tracing so positioned (used as a negative) that the light must pass through the tracing to reach the sensitized paper a chemical reaction is produced in all parts of the print except those which are protected by the opaque (pencil or ink) lines of the drawing. After the paper has been exposed a sufficient length of time, it is removed from the printing frame or machine and subjected to a developing bath and fixing bath, or to a fixing bath only, according to the method employed.

> The important item in making such prints is to be sure that the sensitized paper adheres so closely to the back of the tracing that no light can leak between it and the drawing lines. When space is left between the drawing and the sensitized paper, the lines on the reproduction will be fuzzy.

a. Blueprints. Blueprinting is the oldest and most generally used of the modern processes for reproducing drawings in quantity. They appear to be white line drawings on a blue background. The prints are made by exposing a piece of sensitized paper and a tracing in close contact with each other to sunlight or electric light in a printing frame or machine made for that purpose. Blueprints can be made from a typewritten sheet if carbon backed so as to produce black imprints on both sides of the sheet. Changes may be made on blueprints by using an alkaline solution in a writing or drawing pen.

(1) **Blueprint papers** are available in various speeds and in rolls of various widths, or may be obtained in sheets of specified size. The coated side of fresh paper is a light yellowish-green color. It will gradually turn to a grey-bluish color if not kept carefully away from light, and may eventually be rendered useless. For this reason, it must be kept wrapped or be stored in light-tight containers. The length of exposure depends NOT only upon the kind of paper used and the intensity of the light, but also upon the age of the paper. "The older the paper the quicker it prints and the longer to wash; the fresher the paper the slower it prints and the quicker to wash."

(2) **Sun frame.** The simplest equipment for making blueprints is a sun frame. It has a glass front and removable back, somewhat like a picture frame. In loading: the back is removed and the drawing is inserted with the inked side against the glass; the blueprint paper is placed with its sensitive side against the drawing; and the back of the frame is closed (anchored) so that it exerts enough pressure to insure a perfect adherence of the tracing and the paper. When the glass front

of the frame is exposed to bright sunlight, the sensitized paper will print in from 20 seconds to 4 minutes.

> The fact that prints can only be made when the sun is shining is an inherent disadvantage of the sun frame. Also, large drawings cannot be printed because frames to accommodate them would be too cumbersome to handle.

(3) Development. After exposure, the blueprint paper is washed in clear water and the parts that were exposed to light turn dark blue; the parts that were protected from the light by the lines on the drawing wash clean of the chemical coating, leaving the original white paper. Dipping the blueprint in a solution of potassium dichromate fixes it. Fixing makes it more permanent. Then it is washed in clear water a second time.

(4) Blueprinting machines. Modern blueprint machines are available in non-continuous types in which cut sheets are fed through the blueprint machine for exposure only and then washed in a separate washer. The continuous blueprint machine combines exposure, washing and drying in one continuous operation. Both types of machines use carbon arcs as the light source.

b. Vandyke prints and blueline prints. A vandyke print is composed of white lines on a dark brown background made by printing, in the same manner as for blueprinting, upon a special thin paper from an original pencil or ink tracing. Vandykes can be used as negatives from which to print other duplicates, whereas this is not true of blueprints; then this negative can be printed on blueprint paper, giving a positive print with blue lines on white. The reversed blueprint or "blueline blueprint" is often preferred because it can be easily marked on with an ordinary pencil or pen. Blueline prints have the disadvantage of soiling easily with handling in the shop.

(1) Vandyke paper is a thin, sensitive paper which turns brown when it is exposed to light. Since vandyke paper is transparent, the lines on a vandyke (brownprint) are transparent. Therefore it is used as a negative from which to make other prints.

(2) Printing and developing. As has already been indicated vandykes may be made on regular blueprint machines. However, different chemicals are used in coating the paper and fixing it after it has been printed. The developing solution, commonly called **hypo,** is made of four ounces of fixing salts to a gallon of water. Vandykes must be dried like blueprints after they are developed. A set of two liquids is available for making changes on vandykes.

c. Ozalid prints. Ozalid prints are used extensively when positive prints are desired. They may have black, blue, or red lines on white backgrounds, according to the type of paper used. All have the advantage of being easily marked upon with pencil, pen, or crayon.

(1) Ozalid paper is coated with certain dyestuff intermediates which have the characteristic of decomposing into colorless substances when exposed to actinic (ultraviolet) light. On the other hand, they react with coupling components to form diazo dyestuff (the printed lines) upon exposure to ammonia vapors. Unlike blueprint paper, ozalid materials can be handled under normal indoor illumination.

(2) **Printing and developing.** The ozalid method of reproduction is based upon the transmission of light through the original for the reproduction of positive prints. There is no negative step involved; positive prints are made directly from the drawing tracings. The subject matter may be pen or pencil lines, typewritten or printed matter, or any opaque subject. It involves two simple steps—exposure and dry development. Exposure is made in a printer equipped with a source of ultraviolet light, for example, a mercury vapor lamp, carbon arc, or even by sunlight. A regular blueprint machine may be used. The exposed print is dry developed in a few seconds in an ozalid developer which releases ammonia vapors. A special ozalid machine combines exposure and development in one continuous operation.

d. **Black and white (BW) prints.** BW prints have black lines on a white background and like ozalid prints may be made from ordinary pencil or inked tracings by exposure in the same manner as for blueprints, directly upon special blackprint paper. Exposure may be made in a blueprint machine or any machine using light in a similar way. However, the prints are not washed, as in blueprinting, but must be fed through a special developer which dampens the coated side of the paper to bring out the black lines of the print. A popular printer exposes and develops BW paper in two separate operations: (1) the tracing and BW paper are fed into the printer slot, and when they emerge, (2) the BW paper is then fed through the developer slot. Within a minute or two after developing, the prints are practically dry and are ready for use.

BW prints, together with ozalid prints, are coming into greater use and eventually may largely replace the more cumbersome blueprint process.

4. PHOTOSTATS

The photostat machine is essentially a specialized camera. Photostats are printed by focusing the image through a lens, as in the making of a photograph. Unlike a photograph, the photostat negative as well as the positive is made directly on sensitized paper rather than on film. Also, photostat negatives are not reversed images as are photographic negatives. A photostat print may be the same size, larger, or smaller than the original; large drawings can even be reduced to letter size for use in engineering reports.

a. **Procedure.** The original may be transparent or opaque. It is simply fastened in place and the camera is adjusted to obtain the desired print size. The print is made, developed, and dried in the machine with no dark room required. The result is a negative print with white lines on a near-black background. A positive print having near-black lines on a white background is made by photostating the negative print.

b. **Disadvantages.** Photostats have certain inherent disadvantages as compared with contact prints. Even the best photostats are not as clear as good contact prints and there is a certain amount of distortion when they are enlarged or reduced. If just the negative is reduced or enlarged, the distortion is almost imperceptible. If the positive printed from this negative is further reduced or enlarged, the distortion is greater. Another disadvantage of photostats is their size limitation. The maximum size is 24 x 36 inches. If a larger size is required for some types of work, the print must be made in two or more overlapping pieces.

5. COPYING METHODS

Small drawings are often duplicated by such methods as the mimeograph and other forms such as the hectograph or gelatin pad.

a. **Mimeographing.** While mimeographing is especially used for reproducing typed materials, it can also be very satisfactory in reproducing small and fairly simple drawings. The excellence of the reproduction of such drawings will depend upon the skill of the draftsman in drawing upon the stencil. However, mimeograph manufacturers have now developed a photochemical process by means of which a complicated drawing may be reduced and incorporated into the stencil, which is then used to produce very satisfactory prints.

b. **Hectographing.** In the hectographing process an original is produced by typing on plain paper through a special carbon paper or drawing with a special pencil or ink. This original is then placed on a gelatin pad which absorbs the coloring from the lines made on the paper. The original is then removed and prints are made by bringing sheets of blank paper in contact with the gelatin. A number of different machines using this basic principle are available.

c. **Gelatin duplicator.** The gelatin duplicator is used largely in map reproduction to print small quantities of line sketches and to overprint on existing maps. Various colored dyes (inks) are applied to the gelatin surface to form the printing image. This image is printed by placing paper in contact with the gelatin so some of the dye is transferred to the paper. Since the original inked image can only make a limited number of copies (25 to 100) and the ink cannot be replenished, the color intensity diminishes with each impression until the dye is exhausted and prints are illegible.

6. PRACTICE WORK

As in preceding lessons this practice work gives you an opportunity to see for yourself just how well you understand the material presented in this lesson. Solve the following true or false exercises, then check your answers with the solutions at the back of the booklet. If you find that you have missed an answer, refer to the reference given and restudy. DO NOT send in your answers to these exercises.

1. Before working drawings are sent to the shop, exact duplicates are made and filed. T F
2. The best reproduction copies of working drawings are made from inked tracings. T F
3. The method of duplication is partially determined by its intended use. T F

4. In general, all contact printing processes are based upon the action of light on a chemically coated paper. T F

5. To assure clear, sharp lines on any type of duplicate copies, space is left between the drawing and sensitized paper to afford good light action. T F

6. New and unexposed blueprint paper is blue-grey in color. T F

7. A vandyke is used to produce blueline blueprints. T F

8. The ozalid process is based on the action of sunlight on paper sensitized with ammonia vapors. T F

9. BW prints may be developed in a regular blueprint machine. T F

10. A photostat negative presents a reversed image. T F

EXERCISES

First requirement. Multiple-choice exercises 1 through 6 pertain to the general requirements for the reproduction of working drawings.

1.

The drawings used by workmen on the job are almost always:

a. vandyke prints made by a blueprint machine
b. duplicates of the original drawings
c. carbon copies made by mimeographing
d. made by gelatin duplicators

2.

The duplication process used to make extra copies of working drawings is largely dependent on the:

a. kind of equipment available
b. experience of the draftsman with the process
c. probable future need for the original drawing
d. cost as provided in the contract

3.

To obtain clear sharp duplicate copies, it is necessary that the originals be:

a. inked with all lines of equal weight
b. drawn in pencil or ink with uniformly opaque lines
c. folded so that creases do not blank out important lines
d. carefully preserved and filed for future use

4.

Original working drawings prepared for reproduction should be:

a. drawn to same scale as blueprint machine
b. traced in waterproof ink
c. drawn on translucent material
d. carbon backed if drawn by pencil

5.

Drafting requirements for making pencil or inked tracings are:

a. more exacting than drafting work on drawing paper
b. dependent on the type of reproductions to be made
c. usually left up to the draftsman to decide
d. basically the same as for pencil drawings on paper

6.

Which of the following types of drawings are generally inked?

a. general
b. charts
c. structural
d. shop

Second requirement. Solve multiple-choice exercises 7 through 15 to show your understanding of the types and methods of producing contact prints.

7.

In contact printing the tracing generally serves as a:

a. positive
b. negative
c. translucent material
d. opaque medium

8.

Close adherence of the sensitized paper to the back of the tracing prevents:

a. slipping
b. light leaks
c. over printing
d. under exposure

9.

If blueprint papers are not carefully stored away from light rays they will gradually turn:

a. grey-bluish in color and become useless
b. yellowish-green which increases its shelf life
c. greenish-blue in color and become useless
d. yellowish-grey without loss in usefulness

10.

The printing and development time for blueprint paper varies with the age of the paper as follows:

a. older paper prints faster and takes less time to wash
b. fresh paper prints faster and takes less time to wash
c. fresh paper prints slower but takes longer to wash
d. older paper prints faster but takes longer to wash

11.

The fixative used in developing blueprints is:

a. hypo
b. potassium dichromate
c. ammonia
d. fixing salts

12.

When using an inked tracing and vandyke paper in a blueprint machine the first result is a:

a. vandyke negative or white lines on dark brown background
b. vandyke positive or bluelines on white background
c. vandyke negative or brown lines on white background
d. vandyke positive or white lines on blue background

13.

Ozalid prints may be made with red, blue or black lines on a white background by:

a. using print paper of a complimentary color
b. developing the prints in a special color solution
c. selecting print with proper coating for desired color
d. careful development in a regular blueprint machine

14.

The ozalid process consists of two steps as follows:

a. exposure to ultraviolet light and dry development in ozalid vapors
b. exposure to blue light and washing in liquid ammonia
c. exposure to ultraviolet light and dry development in ammonia vapors
d. exposure to ammonia vapors and development in sunlight

15.

The BW process for reproducing drawings uses a special blackprint paper, and is similar to blueprinting but the:

a. operation is too costly for ordinary use
b. exposed papers are passed through a special developer
c. process is slow and the operation is complicated
d. washing process is reversed

Third requirement. Multiple-choice exercises 16 through 20 pertain to photostats and copy processes.

16.

If a drawing must be reproduced in a size smaller or larger than the original, the process best suited would be the:

a. mimeograph
b. photostat
c. gelatin pad
d. hectograph

17.

To obtain nearly black lines on white background by using a photostat machine it is necessary to first:

a. mount the original upside down
b. make a vandyke negative of white lines on brown background
c. use a filter as in making a photograph
d. make a photostat negative of white lines on a near-black background

18.

Satisfactory results in reproducing small drawings by mimeograph is largely dependent on the:

a. draftsman's ability to draw on stencils
b. simplicity of the drawing
c. photochemical process incorporated in the stencil
d. kind and quality of equipment available

19.

In the hectograph process the original is prepared by:

a. drawing on special paper
b. drawing on a gelatin pad
c. a special process camera
d. using special carbon paper or drawing with a special pencil

20.

Which of the following is generally used to overprint colored contours on maps?

a. colorometer
b. photostat machine
c. gelatin duplicator
d. mimeograph

SOLUTIONS TO PRACTICE WORK

If your answer is incorrect, refer to the reference indicated in parentheses.

LESSON 1

1. Your *plate A* should look like figure 1-5. Check your work to see that you have done the following points correctly:
   - *a.* Auxiliary view is correctly located with respect to given views.
   - *b.* Projection lines are properly extended.
   - *c.* Two major dimensions of auxiliary view agree with same dimension in the principal view from which it is taken.
   - *d.* All lines of foreshortened length omitted.

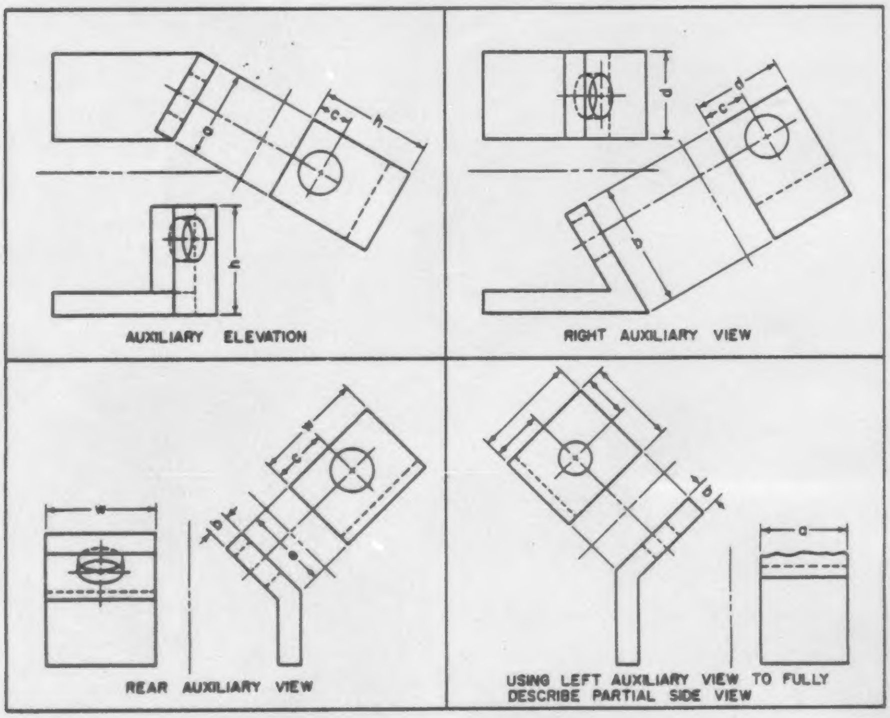

AUXILIARY ELEVATION
RIGHT AUXILIARY VIEW
REAR AUXILIARY VIEW
USING LEFT AUXILIARY VIEW TO FULLY DESCRIBE PARTIAL SIDE VIEW
a
c
h
d
b
w

Figure 1-5. For use with practice exercise 1.

2. T (par 1)
3. T (par 1)
4. F (par 2*d*)
5. F (pars 1 and 3*b*)
6. F (par 2*a*)
7. *a* (pars 1 and 2*a*)
8. *c* (par 1)
9. *b* (par 2*b*)
10. *d* (par 3*b*)
11. *c* (par 4)
12. *b* (par 4)
13. *c* (par 4*c*)
14. *d* (par 5)
15. *d* (par 6)

LESSON 2

Exercises 1 through 4. Your *plate D* should look like figure 2-13. Check your work carefully to be sure that projected measurements are in the proper direction for all dimensions, and that the isometric drawing of each object is complete. Note omission of hidden lines.

5. F (pars 2*a* and 3*a*)
6. T (par 3*a*)
7. F (par 3)
8. F (par 3*c*)
9. T (par 3*d*)
10. T (par 1)

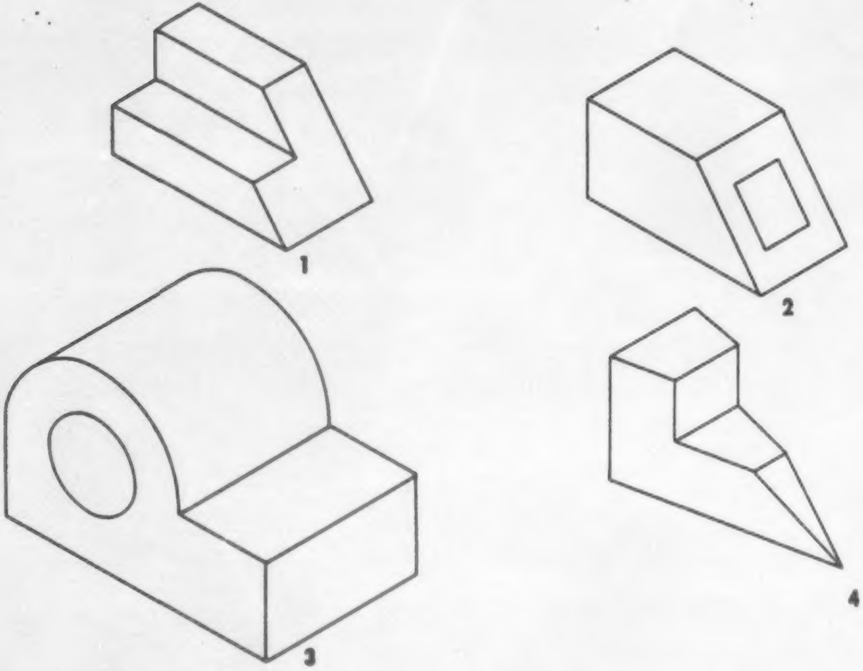


Figure 2-13. For use with practice exercises 1 through 4.

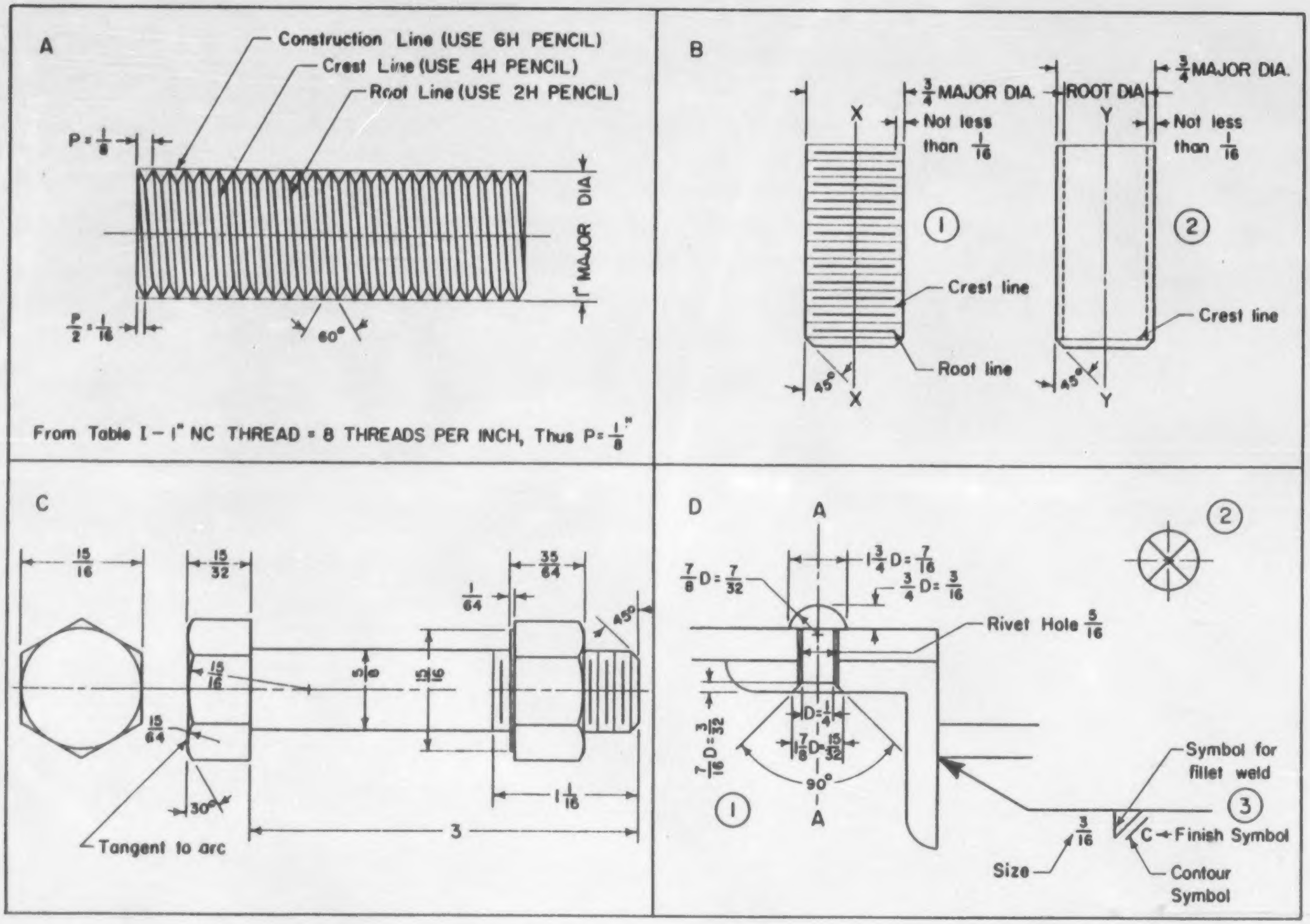

A
Construction Line (USE 6H PENCIL)
Crest Line (USE 4H PENCIL)
Root Line (USE 2H PENCIL)
P = 1/8
P/2 = 1/16
60°
1" MAJOR DIA
From Table I - 1" NC THREAD = 8 THREADS PER INCH, Thus P = 1/8"
B
3/4 MAJOR DIA.
Not less than 1/16
ROOT DIA
X
Y
1
2
Crest line
Root line
45°
C
15/16
15/32
1/64
35/64
45°
5/8
15/16
15/64
30°
1 1/16
3
Tangent to arc
D
A
7/8 D = 7/32
1 3/4 D = 7/16
3/4 D = 3/16
Rivet Hole 5/16
D = 1/4
1 7/8 D = 15/32
7/16 D = 3/32
90°
Symbol for fillet weld
C
Finish Symbol
Contour Symbol
Size
3/16
1
2
3

Figure 3-18. For use with practice exercise 1.

LESSON 3

1. Your *plate G* should look like figure 3-18. Check your work carefully to be sure that the drawing requirements of each block A through D have been followed correctly. In particular, compare the following:
   - *a.* Line weights (did you use the proper pencil?).
   - *b.* Block A should show 8 threads per inch (see table I).
   - *c.* In block B, did you chamfer the bottom ends at 45°?
   - *d.* Did you apply the correct formulas in drawing the bolthead and nut (block C)?
   - *e.* Did you use the correct weld symbols for the welding symbol (item 3, block D), and were they correctly located?

2. F (par 2)
3. F (par 2*a*)
4. F (par 3*b*)
5. F (par 4*b*)
6. *c* (par 2*a*)
7. *b* (par 2*b*)
8. *d* (par 3*a*)
9. *c* (par 4*a*)
10. *c* (par 5*c*)

LESSON 4

1. Your *plate I* should look like figure 4-31.

   Note. To determine the number of risers:

   Let 8′-2″ = 98 inches, then

   try $\frac{98}{6.5} = 15.077$ (not even)

   try $\frac{98}{7} = 14.0$ (even)

   try $\frac{98}{7.5} = 13.066$ (not even)

   Use 14 steps with 7″ rise and 11″ tread. This is standard 18″ rise and tread.

2. T (par 1)
3. F (par 3*b*)
4. F (par 5*c*(4))
5. T (par 5*c*(9))
6. F (par 6)
7. T (par 7*b*)
8. F (par 7*d*)
9. T (par 8)
10. T (par 8*e*)
11. T (par 9*a*)

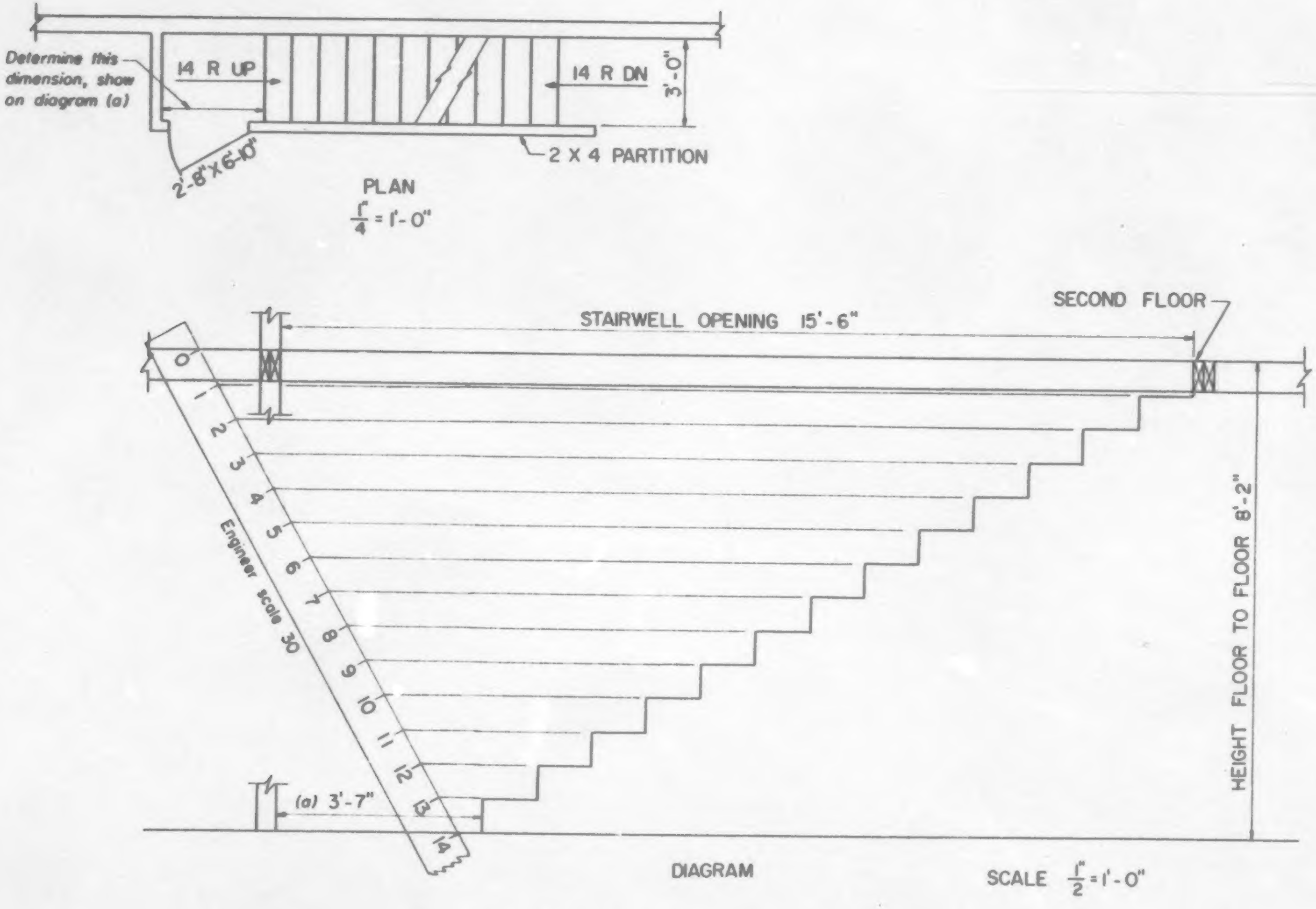

Determine this dimension, show on diagram (a)
14 R UP
14 R DN
3'-0"
2'-8"X6'-10"
2 X 4 PARTITION
PLAN
$\frac{1}{4}$" = 1'-0"
SECOND FLOOR
STAIRWELL OPENING 15'-6"
Engineer scale 30
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
(a) 3'-7"
HEIGHT FLOOR TO FLOOR 8'-2"
DIAGRAM
SCALE $\frac{1}{2}$" = 1'-0"

Figure 4-31. For use with practice exercise 1.

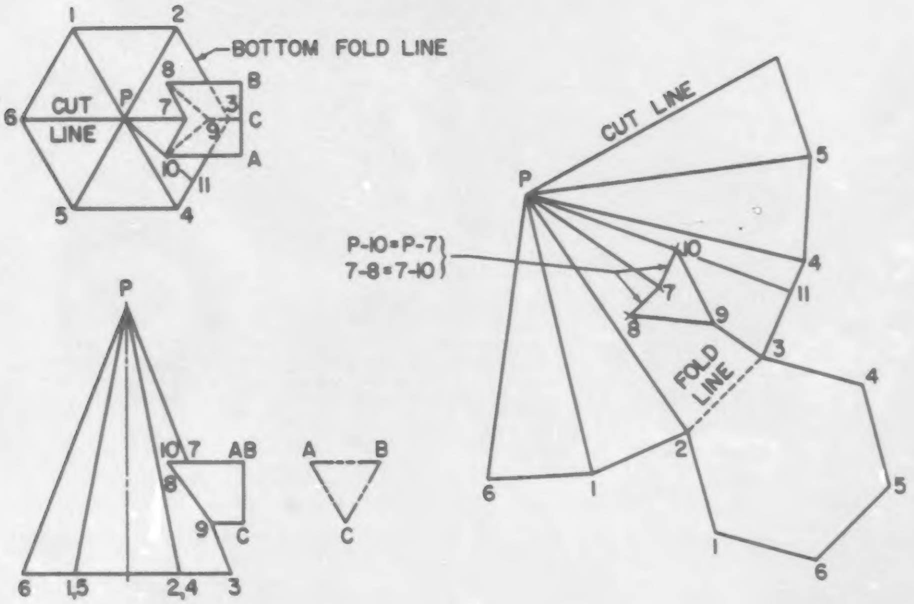


Figure 5-8. For use with practice exercise 1.

LESSON 5

1. Your *plate K* should look like figure 5-8. In checking your work note the following:
   - *a.* Point number 7 is located in the front view at the intersection of the pyramid (P-3) with the upper plane surface of the prism as shown by edge AB in the phantom side view.
   - *b.* Point number 9 is located at the intersection of the edge P-3 with the lower edge of the prism shown at C in the phantom side view.
   - *c.* The upper plane surface of the prism 7-AB is *parallel* to the base plane of the pyramid. Hence the face plane of the pyramid P 3-4 cuts the two parallel planes in parallel lines shown as 7-10 and 3-4 in the top view. Also lines 7-8 and 2-3 are parallel.
   - *d.* Points 8 and 10 are fixed by drawing horizontal edges of prism B to 8 and from A to 10 in the top view.
   - *e.* The development is constructed by using the true lengths of the edges of the pyramid as shown by P-6 or P-3 in front view, and true length of base lines 6-1, 1-2, and so on, from top view.
   - *f.* Points 7 and 9 are easily located in the development from true lengths P-7 and P-9 in front view.
   - *g.* To locate point 10 on the development, P-10 is drawn in the top view and then extended to intersect baseline 3-4 at point 11. The distance 4-11 is a true length in the top view and is transferred to 4-11 in development.

The true length of P-10 is determined as described in paragraph 3*c* (lesson 5) of the attached memorandum, and transferred to the development to locate point 10. Point 8 is located in the same manner.

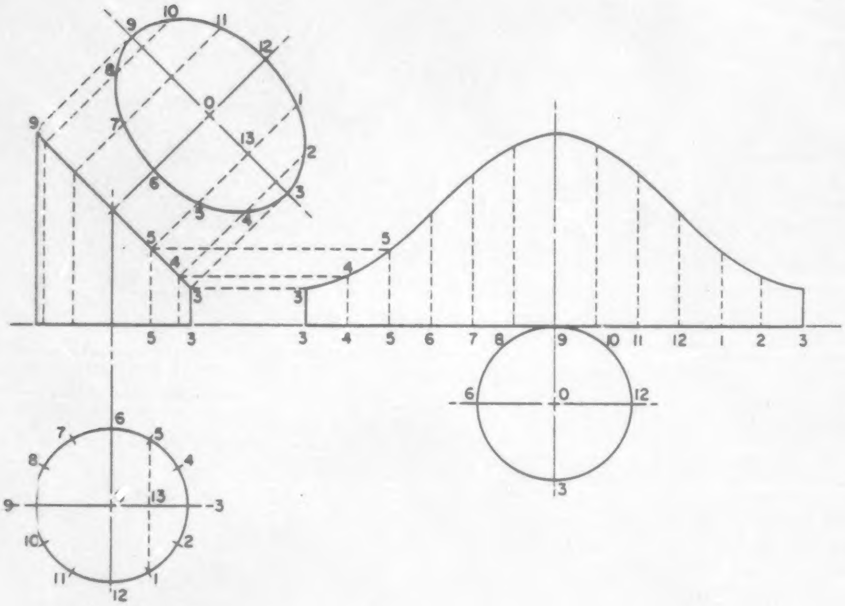


Figure 5-9. For use with practice exercise 2.

2. Your *plate L* should look like figure 5-9. In checking your work note the following:
   - a. Since all elements of the cylindrical surface are parallel to the vertical plane of projection, their true length is taken directly from the front view.
   - b. The bottom view is used to find the length of the stretchout line by stepping off the same number of subdivisions as indicated by the numbered elements.
   - c. The upper base is projected on an auxiliary plane parallel to it.
   - d. Each chord of the upper base (for example 5-1) is parallel to the base plane, and its true length is determined in the bottom view as the chord 5-1 passing through the major axis at point 13. The dividers are set at half the chord length to locate points 5 and 1 in the auxiliary view.

3. F (par 1)
4. T (par 2)
5. F (par 3)
6. T (par 1)
7. F (par 2*a*)
8. F (par 2*b*)
9. T (par 3*c*)
10. F (par 2*c*)

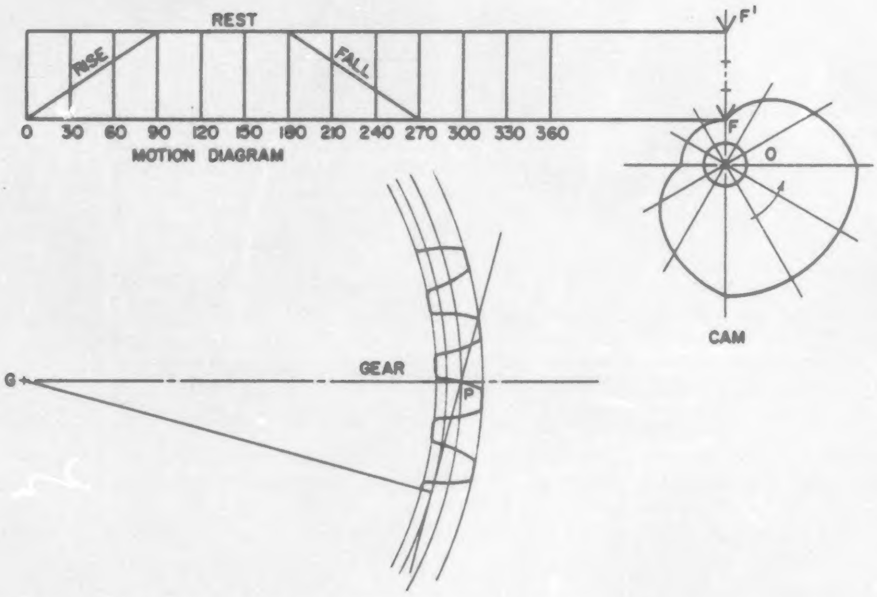

REST
RISE
FALL
F'
F
0 30 60 90 120 150 180 210 240 270 300 330 360
MOTION DIAGRAM
O
CAM
GEAR
G
P

Figure 6-15. For use with practice exercises 1 through 4.

LESSON 6

1. The motion diagram for exercise 1 is constructed as shown on figure 6-15.
2. Your plate cam should check with the cam shown on figure 6-15.
3. The gear calculations for exercise 3 are as follows:

   $P_d = N/D = 40/10 = 4$

   $D_o = (N + 2)/P_d = (40 + 2)/4 =$ *10.5* inches, or $R_o = 5.25$ inches

   $a = 1/P_d = 1/4 =$ *0.25* inches

   $b = 1.157/P_d = 1.157/4 = 0.289$ or *0.29* inches

   $D_R = D - 2b = 10 - 2 \times 0.289 = 9.422$ or $R_R = 4.711$ inches

   $p = \pi/P_d = 3.14/4 =$ *0.786* inches

   $t = p/2 = 0.786/2 =$ *0.393* inches
4. The gear required in exercise 4 is shown on figure 6-15.

   Radius of base circle = *4.82* inches

   Radius of tooth face = ¼ pitch radius = 5/4 = *1.25* inches

5. T (par 1*b*)
6. F (par 1*d*)
7. T (par 2)
8. F (par 3*c*)
9. F (par 4)
10. T (par 5*a*)

LESSON 7

1. Your *plate R* should look like figure 7-12. Check your work carefully to be sure that you have used the correct line conventions.

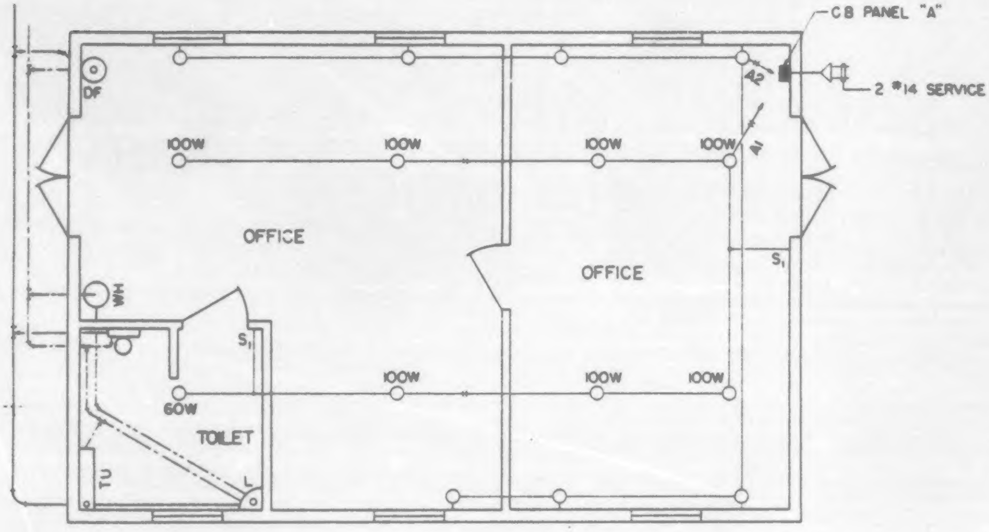

CB PANEL "A"
2 #14 SERVICE
A2
A1
DF
100W
100W
100W
100W
OFFICE
OFFICE
S1
WH
S1
100W
100W
100W
60W
TOILET
TU
L

Figure 7-12. For use with practice exercise 1.

2. *c* (par 1*a*(1))
3. *b* (par 1*b*)
4. *c* (par 2*d*)
5. *d* (par 3*b*(3))
6. *c* (par 6*c*)
7. T (par 1*b*)
8. F (par 1*b*(2))
9. T (par 4*a*(3))
10. F (par 4*b*(4))
11. T (par 4*c*)

LESSON 8

1. T (par 1)
2. T (par 1*a*)
3. F (par 1*b*)
4. F (par 1*c*)
5. T (par 3)
6. T (par 2)
7. F (par 1*a*)
8. T (par 1*b*)
9. F (par 5)
10. T (par 3)

LESSON 9

1. F (par 1)
2. T (par 2)
3. T (par 2)
4. T (par 3)
5. F (par 3)
6. F (par 3*a*(1))
7. T (par 3*b*)
8. F (par 3*c*(1))
9. F (par 3*d*)
10. F (par 4)

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 131-9 . . . . Engineering Drawing II.
LESSON 1 . . . . Auxiliary Views.

SOLUTIONS

Exercises 1 and 2 have a weight of 25 each.

1. (see solution plate B)

2. (see solution plate C)

Each of exercises 3 through 12 has a weight of 5; paragraph references are to the attached memorandum.

3. *d* (par 1)
4. *b* (par 2*a*)
5. *c* (par 2*c*)
6. *d* (par 3*b*)
7. *b* (par 1)
8. *d* (par 5)
9. *b* (par 5)
10. *a* (par 3*a*)
11. *c* (par 6)
12. *d* (par 6)

All concerned will be careful that neither this solution nor information concerning the same comes into the possession of students or prospective students who have not completed the work to which it pertains.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 131-9 . . . . Engineering Drawing II.
LESSON 2 . . . . Isometric Drawing.

SOLUTIONS

Exercises 1 and 2 have a weight of 25 each.

1. (see solution plate E)

2. (see solution plate F)

Each of exercises 3 through 12 has a weight of 5; paragraph references are to the attached memorandum, other references as noted.

3. *b* (par 3*e*)
4. *d* (full scale: 12″ = 1′-0″)
5. *a* (par 3)
6. *c* (par 1)
7. *a* (par 1)
8. *a* (par 3*c*(2))
9. *b* (par 3*c*(1))
10. *d* (par 2*b*)
11. *c* (par 2*b*)
12. *b* (par 3*d*)

CORRESPONDENCE COURSE OF
U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 131-9 . . . . Engineering Drawing II.
LESSON 3 . . . . Screws, Bolts, Rivets and Welds.

SOLUTIONS

Exercises 1 and 2 have a weight of 25 each.

1. (see upper half of solution plate H)

2. (see lower half of solution plate H)

Each of exercises 3 through 12 has a weight of 5; paragraph references are to the attached memorandum.

3. *c* (par 2*b*(1))

4. *a* (par 2*b*(2))

5. *d* (par 2*c*, table I)

6. *d* (par 3*a*)

7. *b* (par 3*a*)

8. *c* (par 3*b*, fig 3-7)

9. *b* (par 3*a*)

10. *d* (par 4*a*, fig 3-9)

11. *c* (par 4*b*)

12. *a* (figs 3-10 and 3-15)

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 131-9 . . . . Engineering Drawing II.
LESSON 4 . . . . Detail and Assembly Practices.

SOLUTIONS

Exercise 1 has a weight of 20.

1. (see solution plate J)

Each of exercises 2 through 21 has a weight of 4; paragraph references are to the attached memorandum.

2. *b* (par 3)
3. *c* (par 3*a*)
4. *a* (par 3*b*)
5. *d* (par 5*b*)
6. *c* (par 5*b*)
7. *a* (par 5*c*(3))
8. *a* (par 5*c*(4))
9. *c* (par 6*a*(2))
10. *b* (par 6*b*)
11. *c* (par 6*b*)
12. *a* (par 6*c*)
13. *d* (par 7*a*(1))
14. *d* (par 7*a*(2))
15. *b* (par 7*b*(1))
16. *a* (par 7*c*)
17. *b* (par 7*e*)
18. *d* (par 7*e*)
19. *c* (par 8*c*)
20. *b* (par 8*g*)
21. *d* (par 9*b*)

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 131-9 . . . . Engineering Drawing II.
LESSON 5 . . . . Intersections and Developments.

SOLUTIONS

Exercises 1 and 2 have a weight of 25 each.

1. (see solution plate M)

2. (see solution plate N)

Each of exercises 3 through 12 has a weight of 5; paragraph references are to the attached memorandum.

3. *c* (par 1)

4. *a* (par 2)

5. *d* (par 2*a*, *b*, *c*)

6. *b* (par 3)

7. *a* (par 3*a*)

8. *c* (par 1)

9. *b* (par 2*b*, fig 5-2)

10. *d* (par 2*c*)

11. *c* (par 1)

12. *b* (par 3*c*)

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 131-9 . . . . Engineering Drawing II.
LESSON 6 . . . . Machine Drawing.

SOLUTIONS

Exercises 1, 2, and 3 have a weight of 20 each.

1. (see solution plate P)

2. (see solution plate Q)

3. (see solution plate Q)

Each of exercises 4 through 13 has a weight of 4; paragraph references are to the attached memorandum.

4. *d* (par 1)
5. *c* (par 1*c*)
6. *a* (par 2*d*)
7. *b* (solution plate Q)
8. *a* (solution plate Q)
9. *c* (solution plate P)
10. *d* (solution plate P)
11. *b* (par 3)
12. *c* (par 4*b*)
13. *b* (par 5*a*)

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 131-9 . . . . Engineering Drawing II.
LESSON 7 . . . . Architectural and Structural Drawing.

SOLUTIONS

Exercise 1 has a weight of 25.

1. (see solution plate S)

Each of exercises 2 through 16 has a weight of 5; paragraph references are to the attached memorandum.

2. *a* (par 2)
3. *c* (par 2*a*)
4. *c* (par 2*d*(1))
5. *b* (par 2*d*(2))
6. *d* (par 3)
7. *c* (par 3)
8. *a* (par 3*a*)
9. *d* (par 3*d*)
10. *c* (par 4*a*)
11. *b* (par 4*b*)
12. *d* (par 4*c*)
13. *b* (par 5*b*)
14. *c* (par 5*b*(2))
15. *a* (par 5*b*(2))
16. *d* (par 5*b*(3))

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 131-9 . . . . Engineering Drawing II.
LESSON 8 . . . . Map Drawing.

SOLUTIONS

Exercise 1 has a weight of 50.

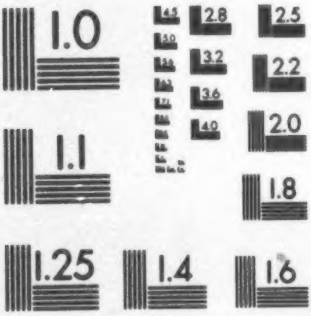
1. (see solution plate T)

Each of exercises 2 through 11 has a weight of 5; paragraph references are to the attached memorandum.

2. *b* (par 1)
3. *c* (par 1*c*)
4. *a* (par 2)
5. *a* (par 2)
6. *d* (par 2)
7. *d* (par 3)
8. *b* (par 4)
9. *c* (par 5)
10. *b* (par 4*a*)
11. *d* (par 4*c*)

1

S.T.


1.0
4.5
5.0
5.6
6.3
7.1
8.0
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 131-9 . . . . Engineering Drawing II.
LESSON 9 . . . . Drawing Reproduction.

SOLUTIONS

Each exercise has a weight of 5; paragraph references are to the attached memorandum.

1. *b* (par 1)
2. *a* (par 1)
3. *b* (par 1)
4. *c* (par 1)
5. *d* (par 1)
6. *b* (par 2)
7. *b* (par 3)
8. *b* (par 3)
9. *a* (par 3*a*(1))
10. *d* (par 3*a*(1))
11. *b* (par 3*a*(3))
12. *a* (par 3*b*)
13. *c* (par 3*c*)
14. *c* (par 3*c*(2))
15. *b* (par 3*d*)
16. *b* (par 4*a*)
17. *d* (par 4)
18. *a* (par 5*a*)
19. *d* (par 5*b*)
20. *c* (par 5*c*)

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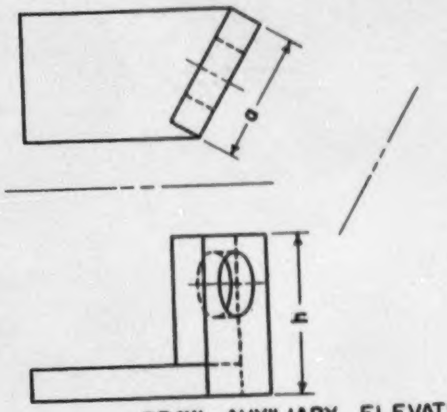
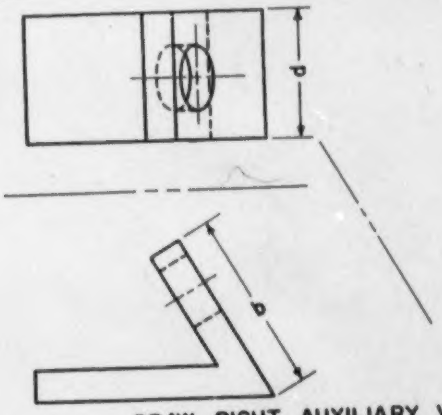
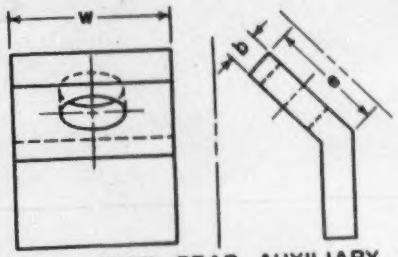
EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL



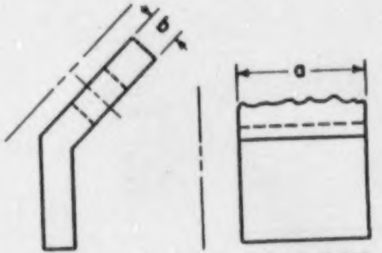
DRAW AUXILIARY ELEVATION



DRAW RIGHT AUXILIARY VIEW



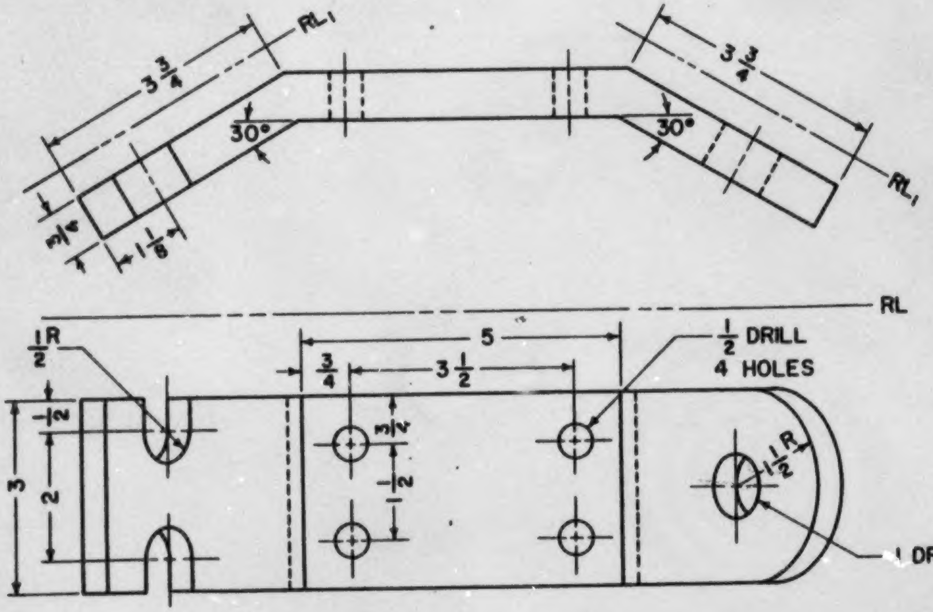
DRAW REAR AUXILIARY VIEW



DRAW LEFT AUXILIARY VIEW TO FULLY DESCRIBE PARTIAL SIDE VIEW

Name Address	ARMY SERIAL No.	LESSON No. 1	SUBCOURSE No. 131	AUXILIARY VIEWS Practice exercise 1	PLATE A
	GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

12 57,717—AG—Ft Belvoir


RL1
$3\frac{3}{4}$
30°
$\frac{3}{4}$
$1\frac{1}{8}$
$3\frac{3}{4}$
30°
RL1
RL
$\frac{1}{2}$R
5
$\frac{3}{4}$
$3\frac{1}{2}$
$\frac{1}{2}$ DRILL
4 HOLES
$\frac{1}{2}$
3
2
$\frac{3}{4}$
$1\frac{1}{2}$
$1\frac{1}{2}$R
1 DRILL

SCALE: 6" = 1'-0"

Name ______ Address ______	ARMY SERIAL No.	LESSON No. 1	SUBCOURSE No. 131	CONNECTOR STRIP Exercise 1	PLATE B
	GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

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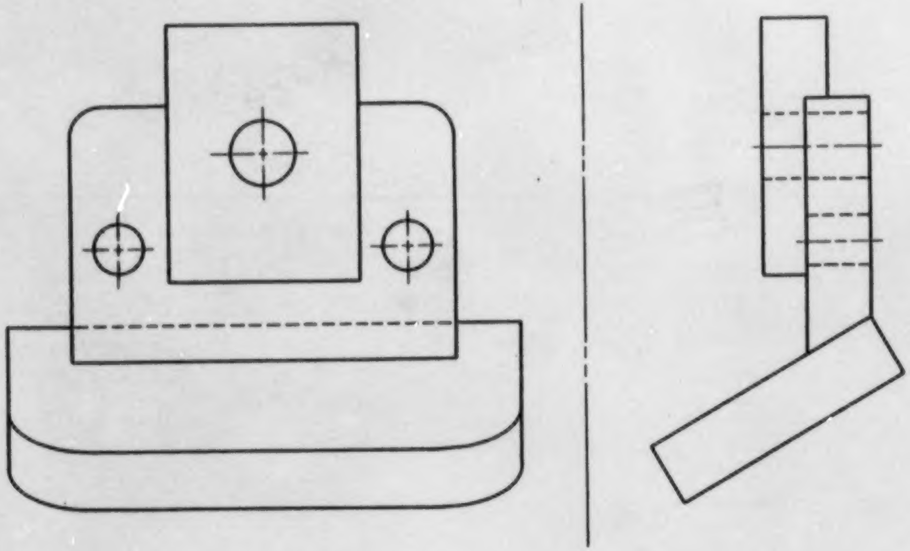
EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL — 177



SCALE: 12" = 1'- 0"

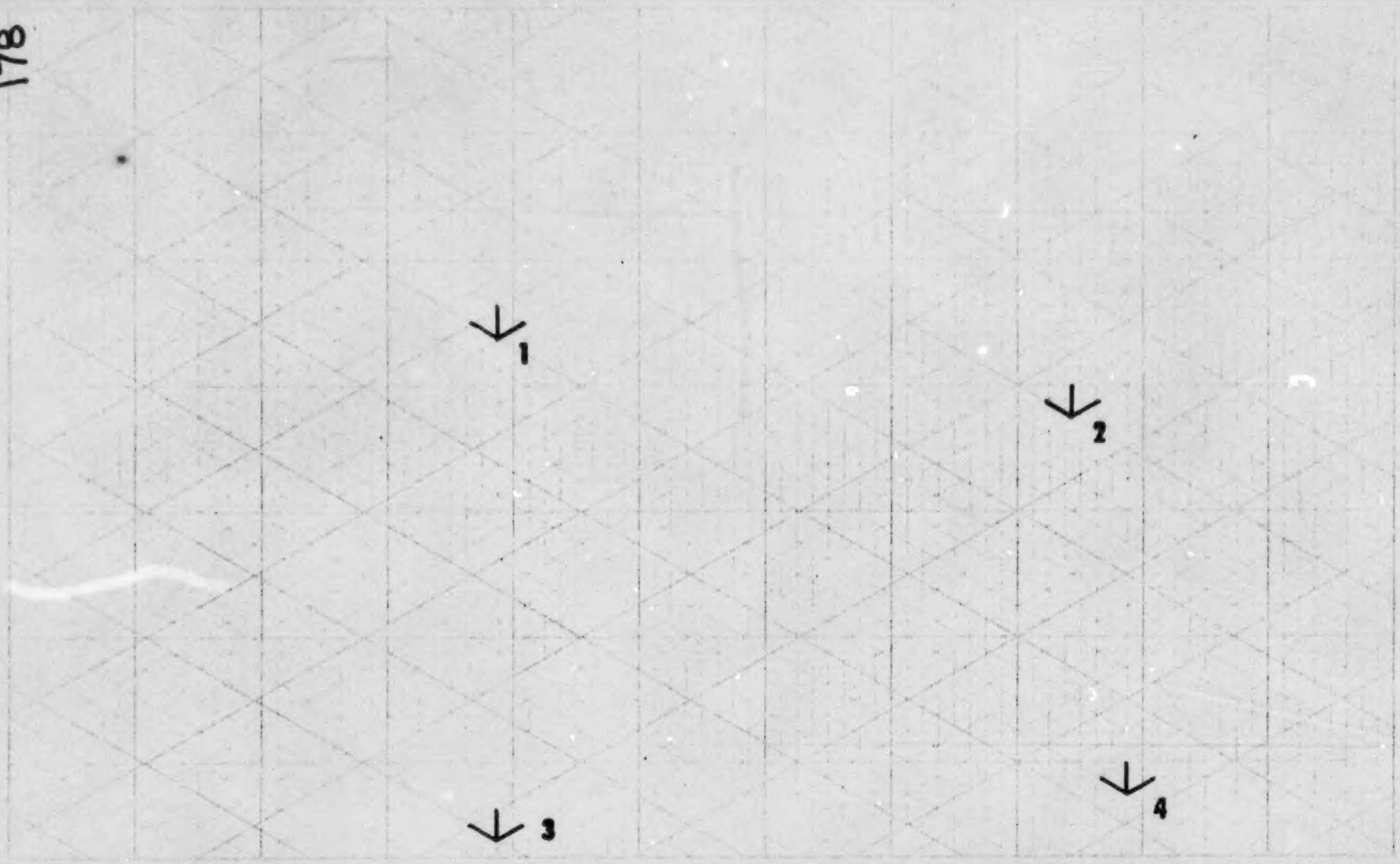
Name________________________
Address ________________________

ARMY SERIAL No.	LESSON No. 1	SUBCOURSE No. 131	**ANGLE BRACE** Exercise 2	PLATE **C**
GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

12 87,717—AG—Ft Belvoir

EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

178



Name ____________________

Address ____________________

____

ARMY SERIAL No.

GRADE

LESSON No. 2

SUBCOURSE No. 131

TITLE OF SUBCOURSE ENGINEERING DRAWING II

ISOMETRIC VIEWS

Practice exercise 1

PLATE D

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Name
Address

ARMY SERIAL No.

GRADE

LESSON No. 2

SUBCOURSE No. 131

TITLE OF SUBCOURSE
ENGINEERING DRAWING II

HINGED CATCH
Exercise 1

PLATE
E

12

-87,717—AO—Ft Belvoir

EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

180

Name Address	ARMY SERIAL No.	LESSON No. 2	SUBCOURSE No. 131	SWIVEL BLOCK Exercise 2	PLATE F
	GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

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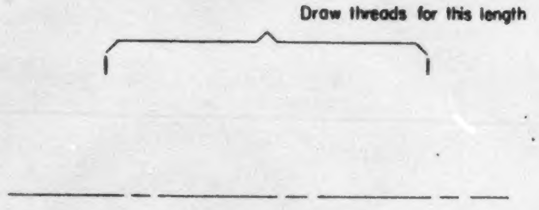
EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

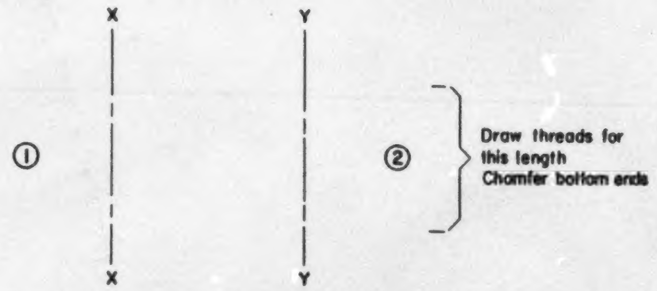
181

A



ON THE GIVEN CENTER LINE DRAW (full size) THE SEMICONVENTIONAL THREADS FOR 1-?NC-2 SCREW.

B

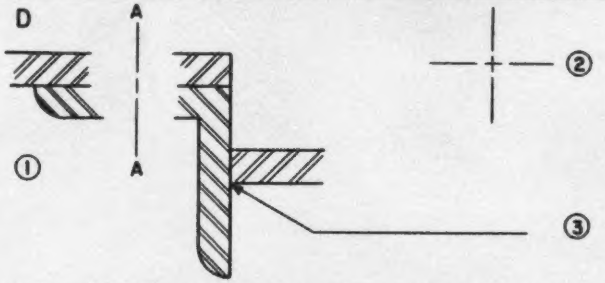


(1) ON CENTERLINE X-X DRAW (full size) THE REGULAR THREAD SYMBOL FOR A 3/4-?NF-2 LH SCREW THREAD.
(2) ON CENTERLINE Y-Y DRAW (full size) THE SIMPLIFIED THREAD SYMBOL FOR THE SAME SCREW THREAD.

C

ON THE GIVEN CENTERLINE, USING APPROXIMATE METHOD, DRAW (full size) A REGULAR SEMIFINISHED HEXAGONAL-HEAD BOLT AND NUT. DIAMETER = 5/8; LENGTH = 3". SHOW WASHER FACE ON NUT ONLY. USE THE REGULAR THREAD SYMBOL.

D

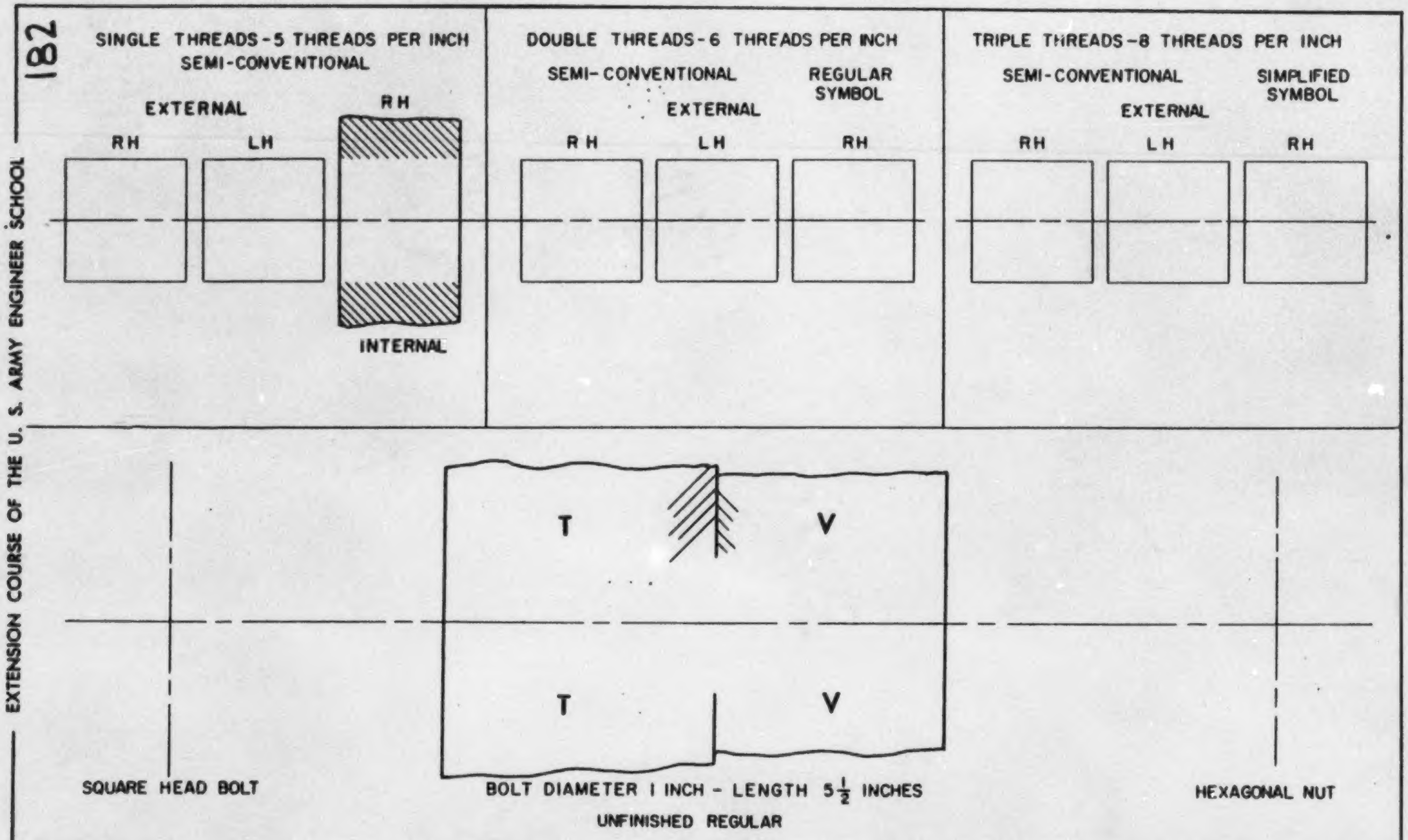


(1) ON CENTERLINE A-A DRAW (full size) A SMALL FORM RIVET WITH BUTTON HEAD AT TOP AND COUNTERSUNK HEAD AT BOTTOM. (D = 1/4")
(2) SHOW SHOP-RIVET CONVENTION, FOR SAME RIVET, COUNTERSUNK AND CHIPPED, FAR SIDE.
(3) COMPLETE WELDING SYMBOL FOR NEAR SIDE, FLUSH-CONTOUR, CHIPPED FINISH, 3/16 ARC FILLET WELD.

Name __________ Address __________ __________	ARMY SERIAL No. GRADE	LESSON No. 3	SUBCOURSE No. 131	THREAD CONVENTIONS, BOLTS & NUTS, RIVETS & WELDING SYMBOLS. Practice Exercise I.	PLATE G
		TITLE OF SUBCOURSE ENGINEERING DRAWING II			

EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

182


SINGLE THREADS-5 THREADS PER INCH
SEMI-CONVENTIONAL
EXTERNAL
RH
LH
RH
INTERNAL
DOUBLE THREADS-6 THREADS PER INCH
SEMI-CONVENTIONAL
EXTERNAL
REGULAR SYMBOL
RH
LH
RH
TRIPLE THREADS-8 THREADS PER INCH
SEMI-CONVENTIONAL
EXTERNAL
SIMPLIFIED SYMBOL
RH
LH
RH
T
V
T
V
SQUARE HEAD BOLT
BOLT DIAMETER 1 INCH - LENGTH 5½ INCHES
UNFINISHED REGULAR
HEXAGONAL NUT

Name ______ Address ______ ______	ARMY SERIAL No.	LESSON No. 3	SUBCOURSE No. 131	SCREW THREADS & BOLT Exercises 1 and 2	PLATE H
	GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

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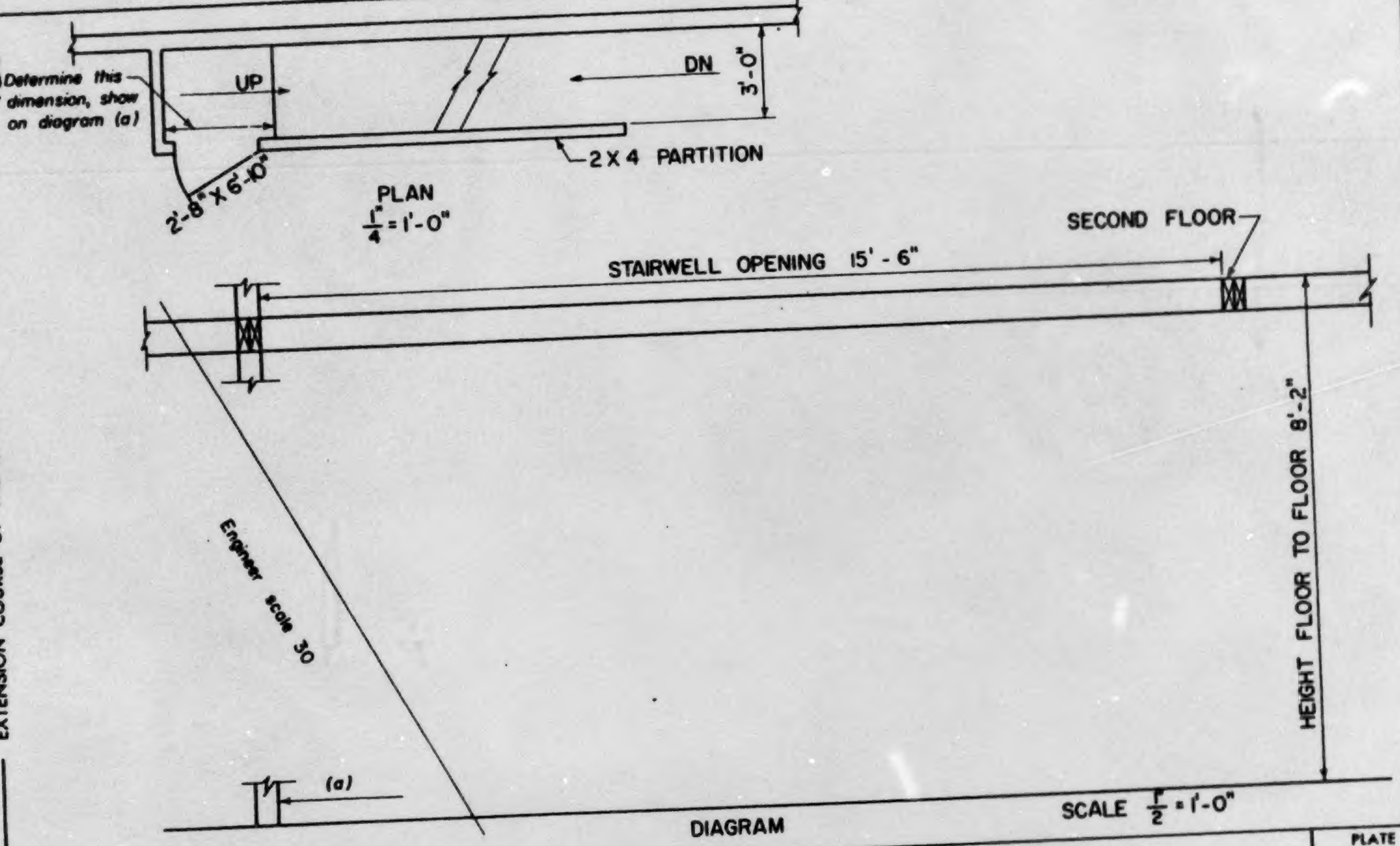
EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL


Determine this dimension, show on diagram (a)
UP
DN
3'-0"
2 X 4 PARTITION
2'-8" X 6'-10"
PLAN
$\frac{1}{4}" = 1'-0"$
SECOND FLOOR
STAIRWELL OPENING 15' - 6"
HEIGHT FLOOR TO FLOOR 8'-2"
Engineer scale 30
(a)
DIAGRAM
SCALE $\frac{1}{2}" = 1'-0"$

Name ____________________
Address ____________________

ARMY SERIAL No.
GRADE

LESSON No. 4
SUBCOURSE No. 131
TITLE OF SUBCOURSE ENGINEERING DRAWING II

STAIRWAY
Practice exercise I

PLATE I

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EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

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Name ______	ARMY SERIAL No.	LESSON No. 4	SUBCOURSE No. 131	BEAM DETAIL	PLATE. J
Address ______ ______	GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II		Exercise 1	

12

-87,717—AG—Ft Belvoir

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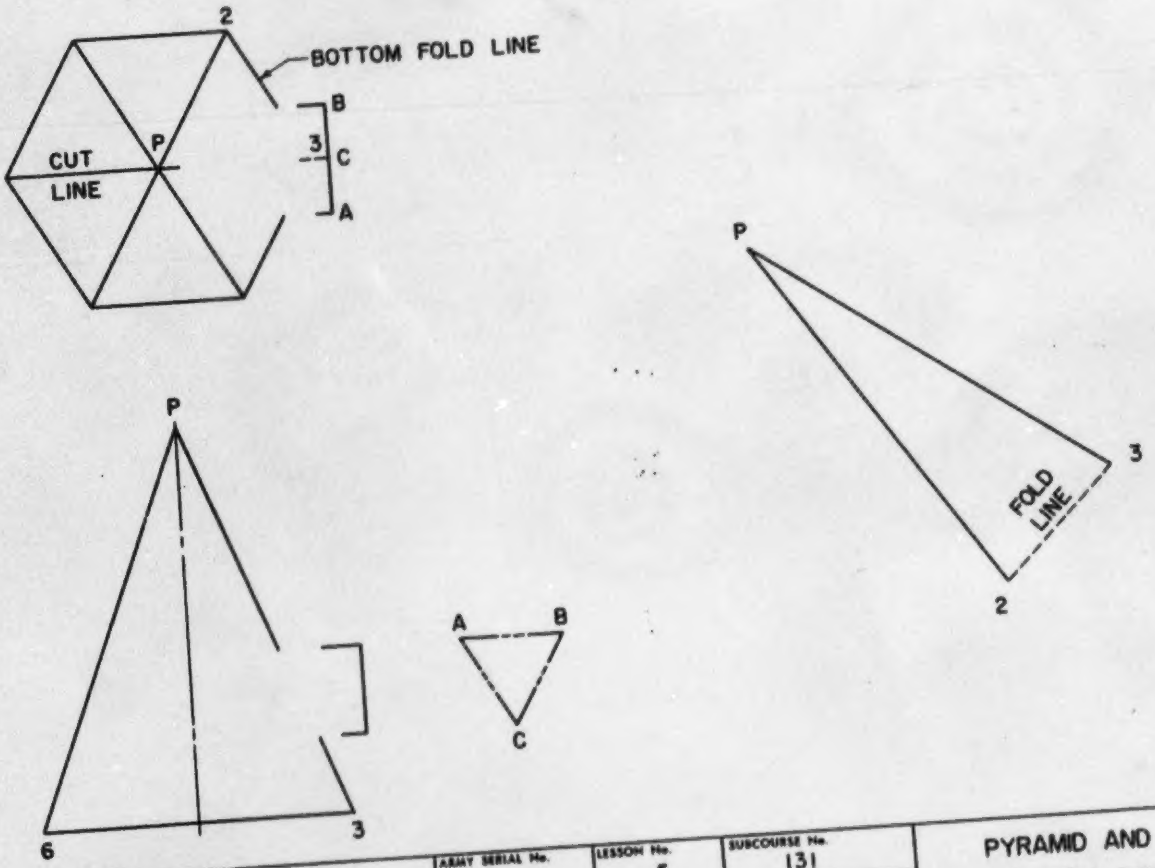
EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

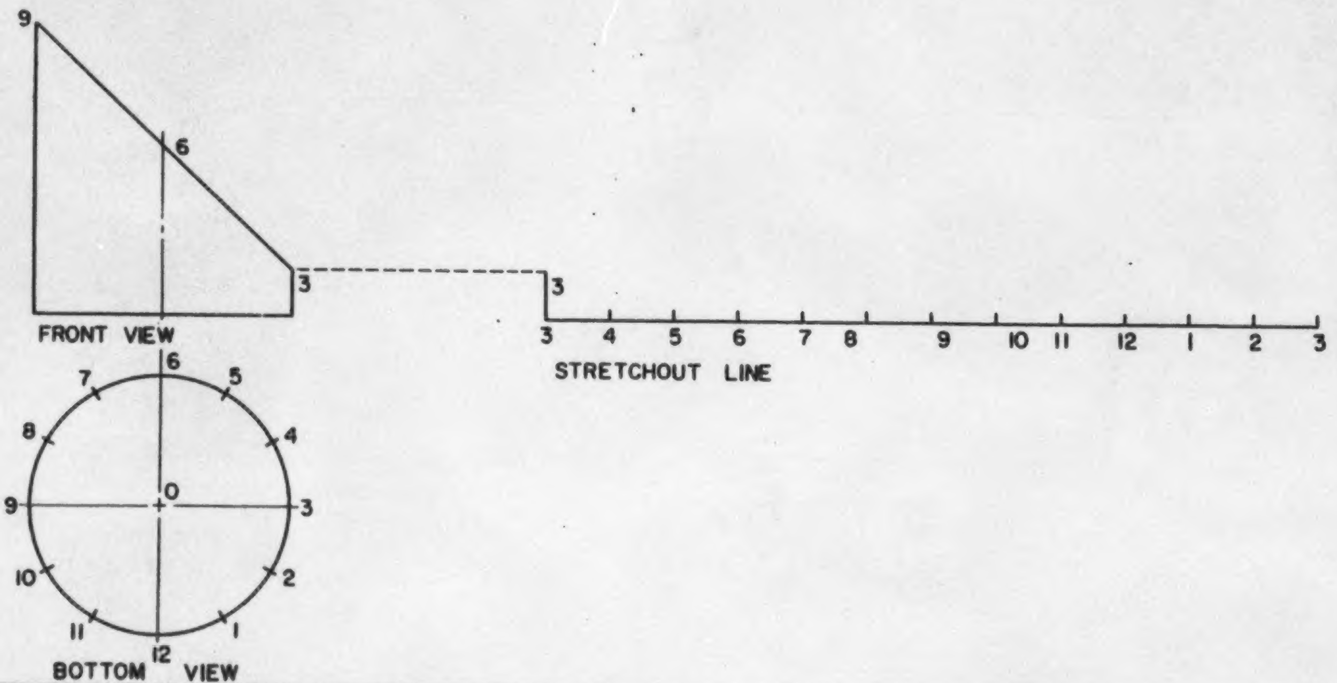

2
BOTTOM FOLD LINE
B
3
C
A
P
CUT LINE
P
6
3
A
B
C
P
3
FOLD LINE
2

Name
Address

ARMY SERIAL No.	LESSON No. 5	SUBCOURSE No. 131	PYRAMID AND PRISM Practice exercise I	PLATE K
GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

12 87,717—AG—Ft Belvoir

EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

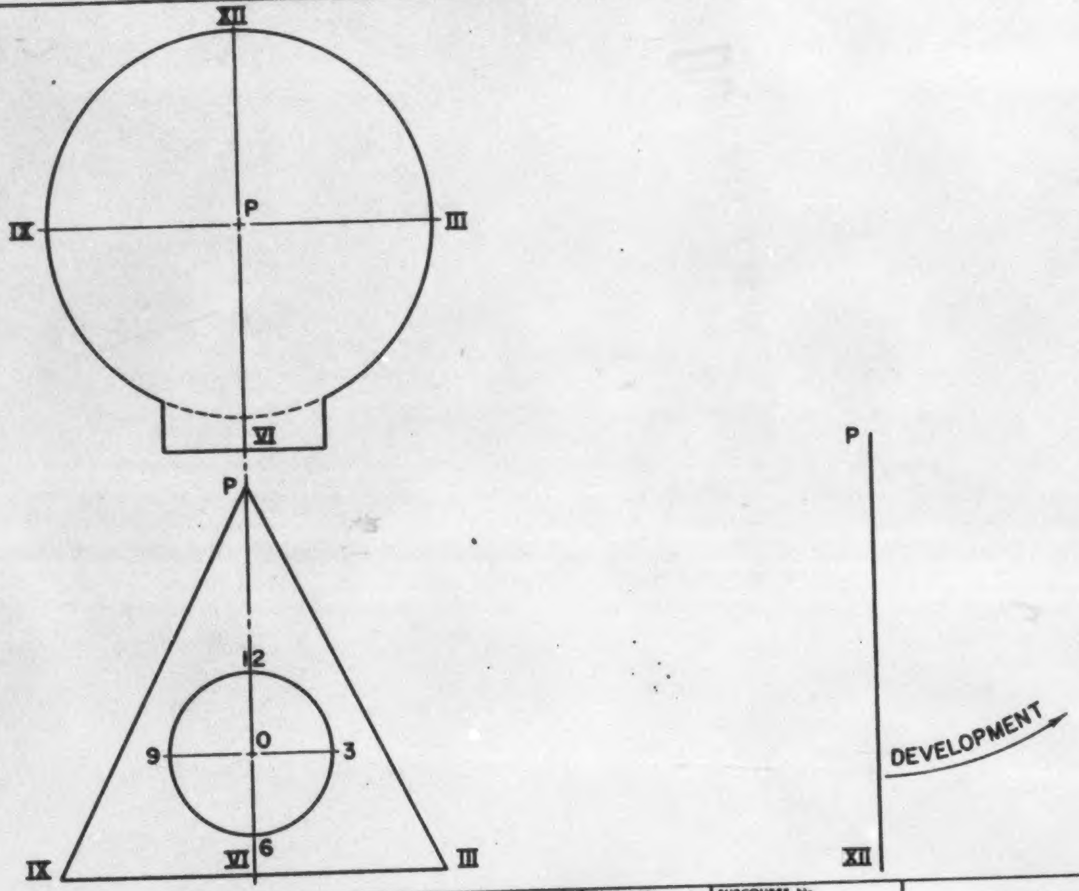

9
6
3
FRONT VIEW
3
3
4
5
6
7
8
9
10
11
12
1
2
3
STRETCHOUT LINE
6
7
5
8
4
0
9
3
10
2
11
1
12
BOTTOM VIEW

Name ____________ Address ____________ ____________	ARMY SERIAL No.	LESSON No. 5	SUBCOURSE No. 131	TRUNCATED CYLINDER Practice exercise 2	PLATE L
	GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

12   -57,717—AG—Ft Belvoir

EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

187


XII
P
IX
III
VI
P
12
O
9
3
6
VI
IX
III
P
XII
DEVELOPMENT

Name	ARMY SERIAL No.	LESSON No. 5	SUBCOURSE No. 131	CYLINDER AND CONE Exercise 1	PLATE M
Address	GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

12

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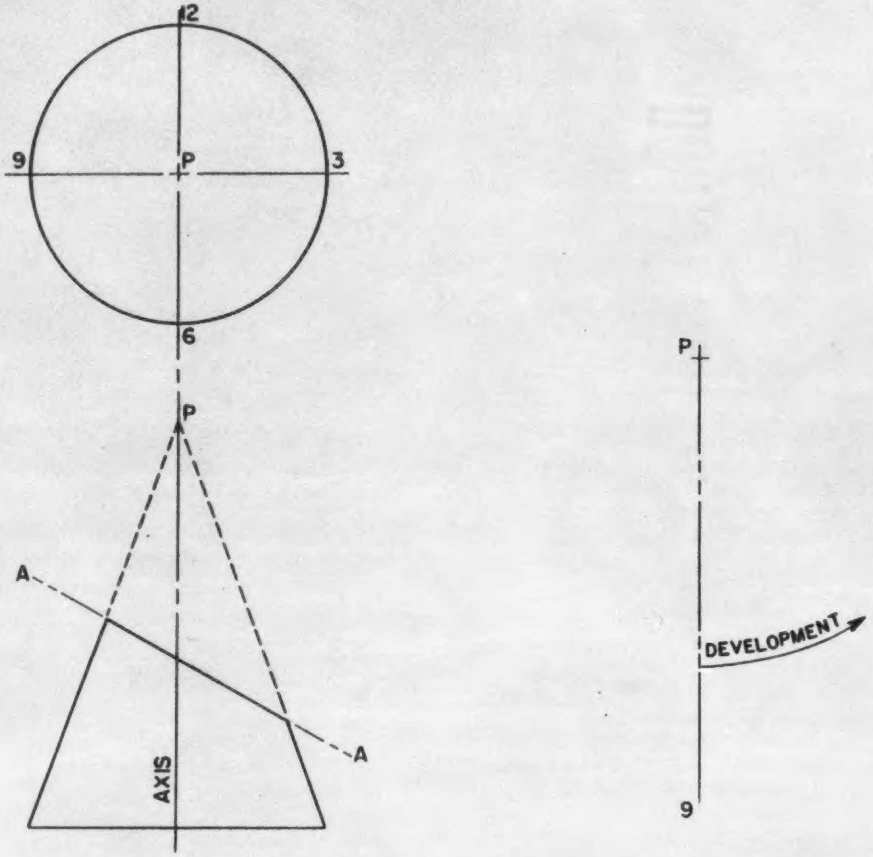
EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

188


12
9
P
3
6
P
A
A
AXIS
P
DEVELOPMENT
9

Name ______________________

Address ____________________

____

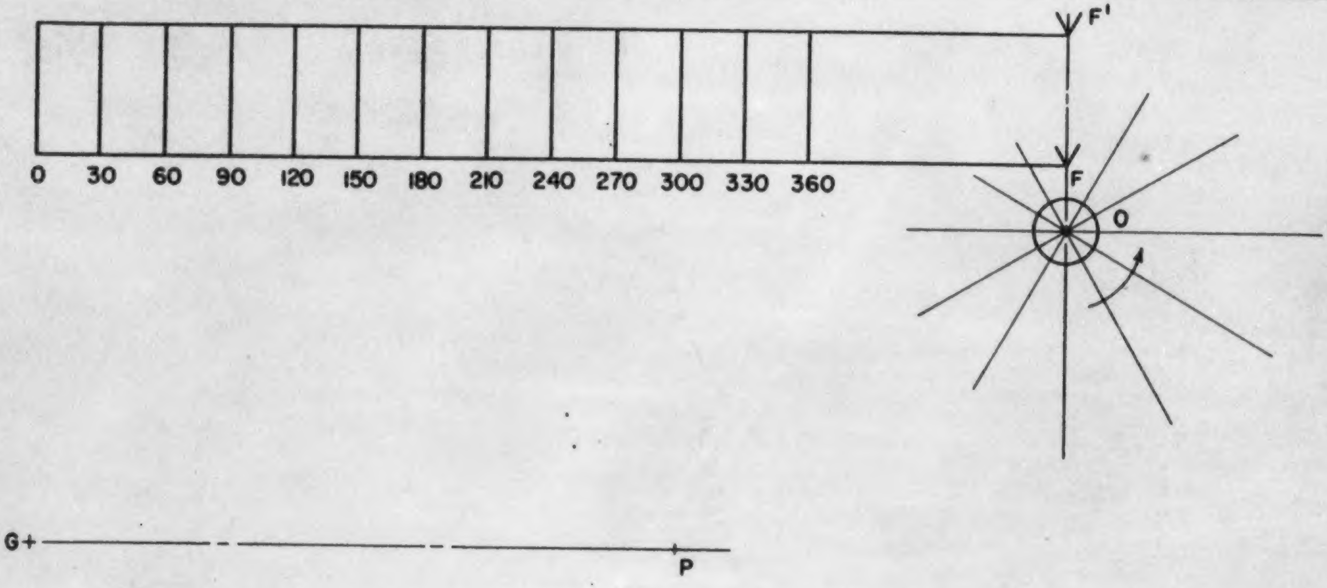
ARMY SERIAL No.	LESSON No. 5	SUBCOURSE No. 131	TRUNCATED CONE Exercise 2	PLATE N
GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

12

-87,717—AG—Ft Belvoir

189

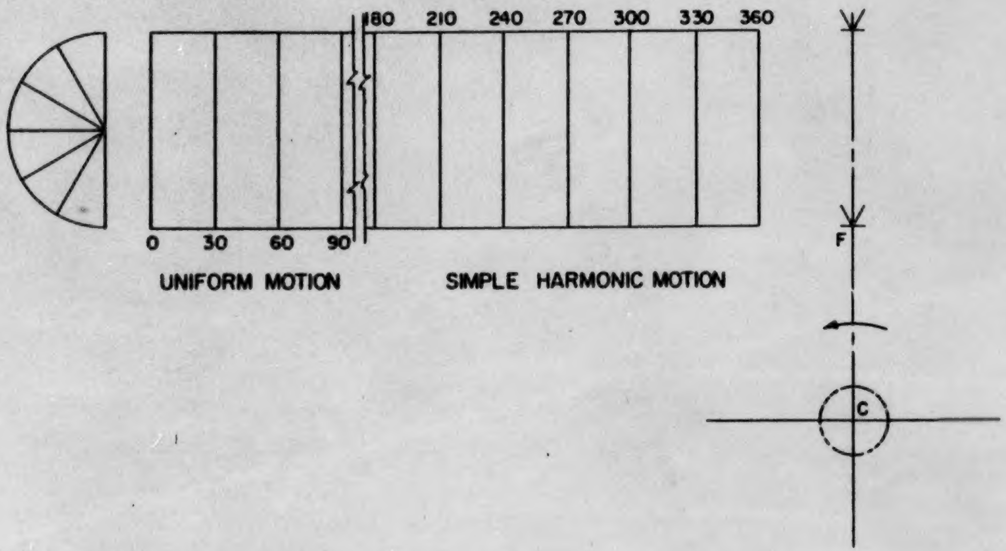
EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL


F'
0
30
60
90
120
150
180
210
240
270
300
330
360
F
O
G
P

Name ______ Address ______	ARMY SERIAL No.	LESSON No. 6	SUBCOURSE No. 131	GEAR AND CAM Practice exercises 1 through 4	PLATE O
	GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

190


180
210
240
270
300
330
360
0
30
60
90
UNIFORM MOTION
SIMPLE HARMONIC MOTION
F
C

Name ________________

Address ________________

ARMY SERIAL No.

GRADE

LESSON No. 6

SUBCOURSE No. 131

TITLE OF SUBCOURSE ENGINEERING DRAWING II

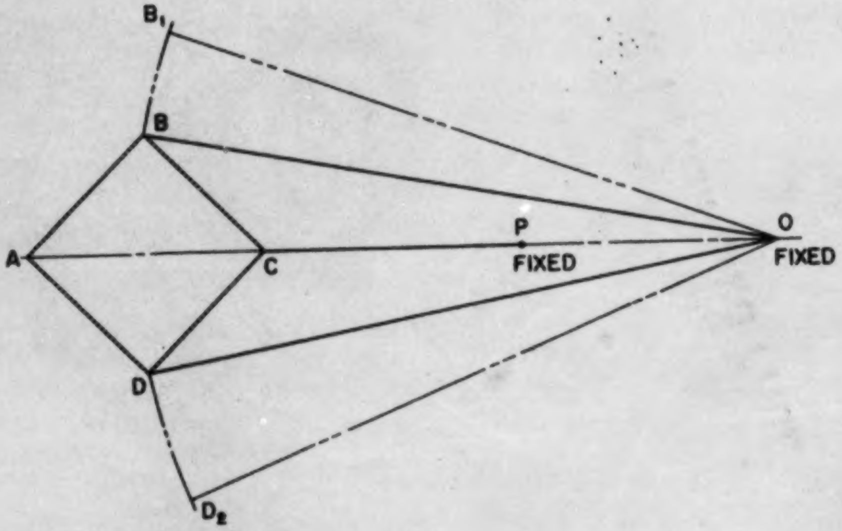
PLATE CAM

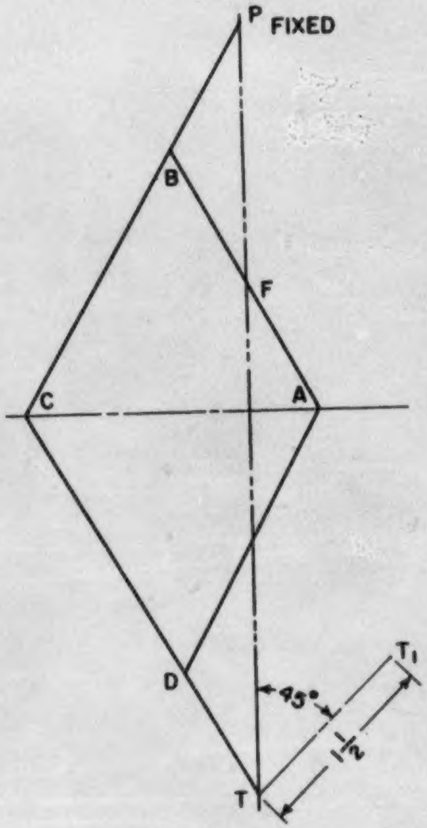
Exercise I

PLATE P

12 -87,717-AG-Ft Belvoir

EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL — 191


B₁
B
A
C
P
FIXED
O
FIXED
D
D₂


P FIXED
B
F
C
A
D
T₁
45°
1 1/2
T

Name ____________________
Address ____________________
____

ARMY SERIAL No.	LESSON No. 6	SUBCOURSE No. 131	LINKAGES Exercises 2 & 3	PLATE Q
GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

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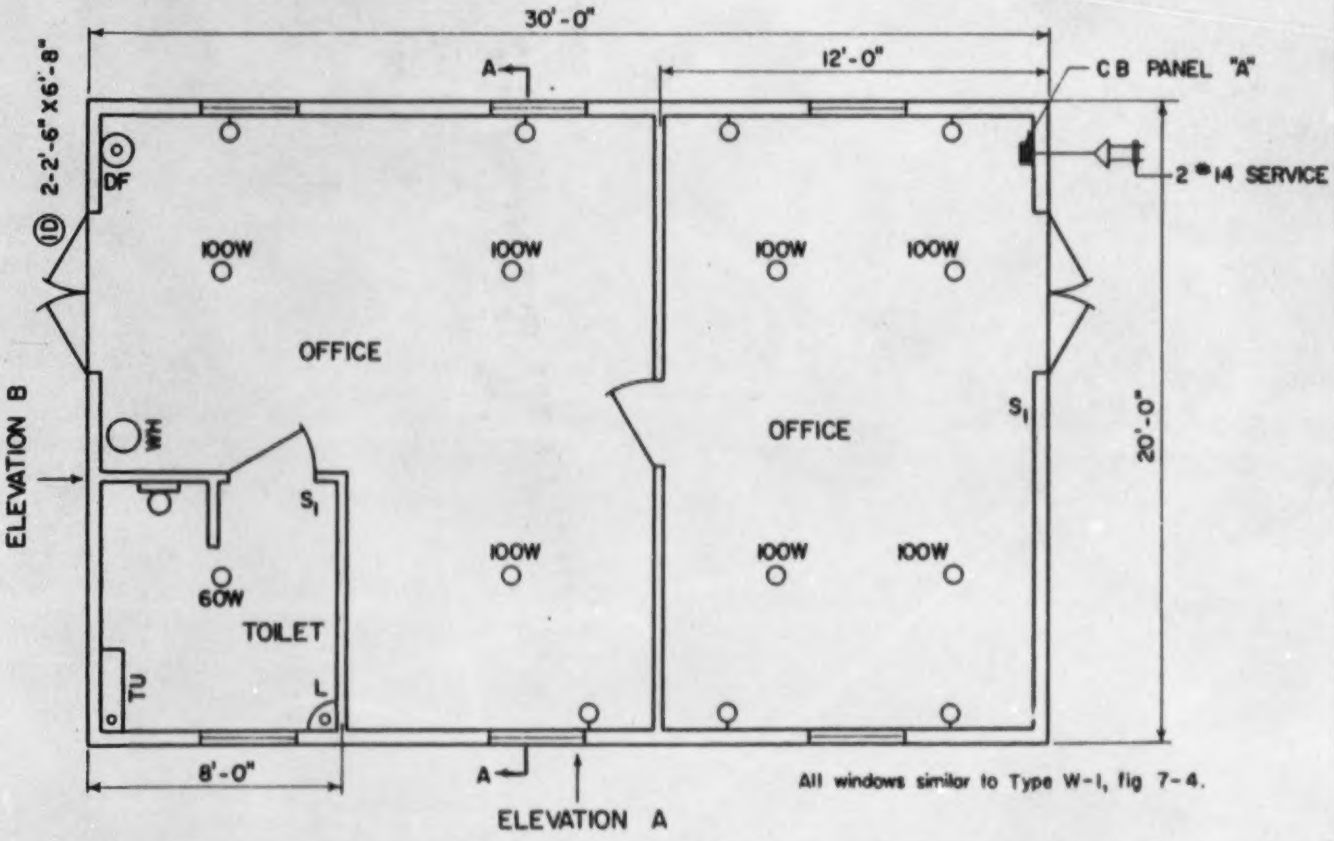
EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL


30'-0"
12'-0"
CB PANEL "A"
2 #14 SERVICE
A
A
2-2'-6" X 6'-8"
1D
DF
100W
100W
100W
100W
OFFICE
OFFICE
S1
S1
WH
ELEVATION B
100W
100W
100W
60W
TOILET
TU
L
20'-0"
8'-0"
ELEVATION A

All windows similar to Type W-1, fig 7-4.

Name ______ Address ______	ARMY SERIAL No.	LESSON No. 7	SUBCOURSE No. 131	PLATE R
	GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II		

FLOOR PLAN - ADMIN. BLDG.
Practice exercise 1

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EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

193

Name ______	ARMY SERIAL No.	LESSON No. 7	SUBCOURSE No. 131	ELEVATIONS Exercise 1	PLATE S
Address ______ ______	GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II			

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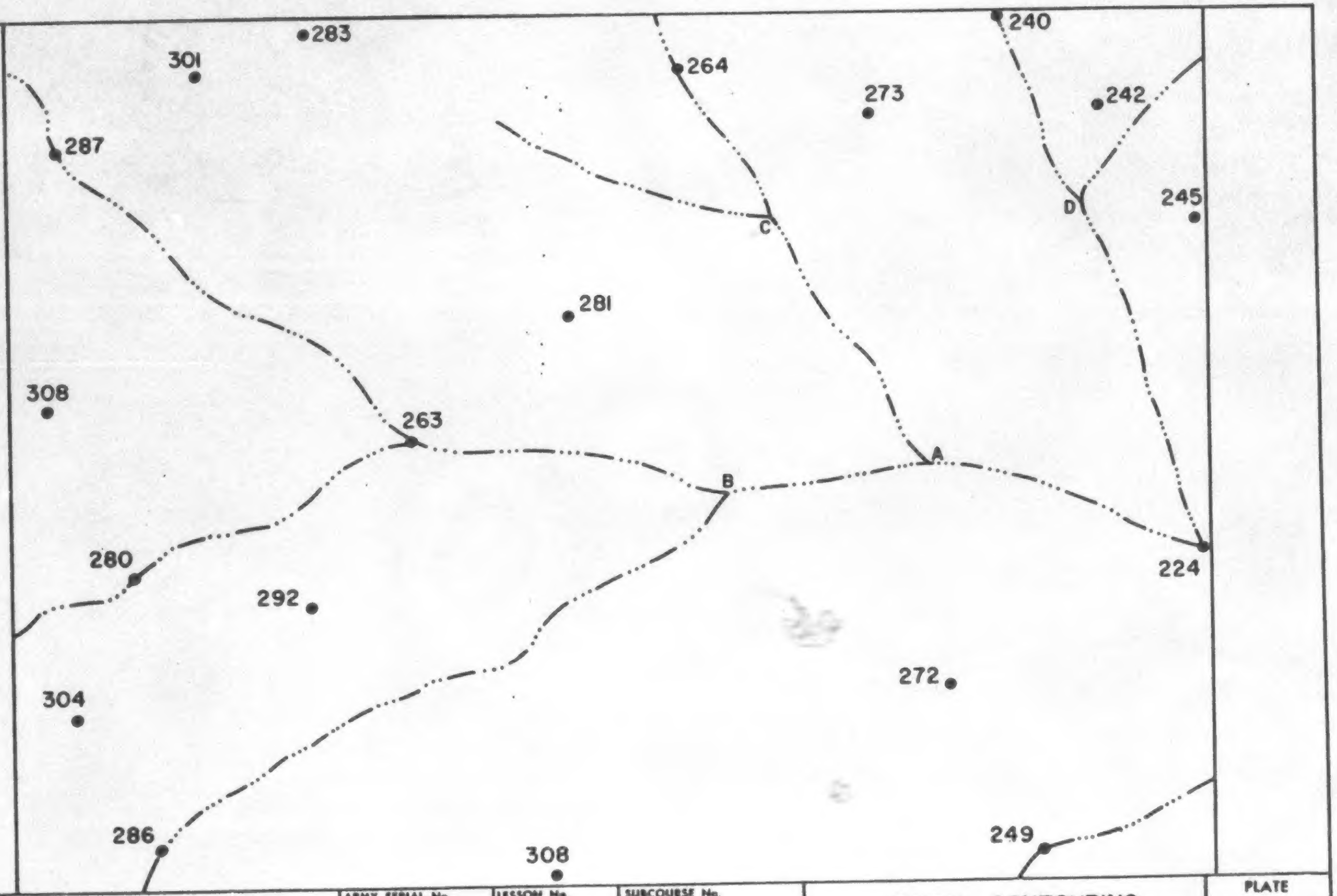
EXTENSION COURSE OF THE U. S. ARMY ENGINEER SCHOOL

194


283
301
264
240
273
242
287
C
D
245
281
308
263
A
B
224
280
292
272
304
286
308
249

Name ______ Address ______	ARMY SERIAL No.	LESSON No. 8	SUBCOURSE No. 131	LOGICAL CONTOURING Exercise I
	GRADE	TITLE OF SUBCOURSE ENGINEERING DRAWING II		PLATE T

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